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GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT INITIATION

Date: April 30, 1974

Project Title: Microearthquake Monitoring, Carter's Dam, Georgia

Project No: G-35-612

Principal Investigator: Dr. Leland T. Long

Sponsor: U.S. Army; Mobile District, Corps of Engineers; Mobile, Alabama

Agreement Period: From March 6, 1974 Until August 15, 1975

Type Agreement: Contract No. DACW01-74-C-0077

Amount: $5,195

Reports Required: Quarterly Letter Reports; Final Report

Sponsor Contact Person (s):

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Thru ORA
Mr. Terence J. Connell
Dept. of the Army
Mobile District, Corps of Engineers
P. O. Box 2288
Mobile, Alabama, 36628

Technical Matters
Mr. Robert Dealy
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Mobile, Alabama 36628

Assigned to: Geophysical Sciences

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RA-3 (6-71)

GEORGIA INSTITUTE OF TECHNOLOGY
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SPONSORED PROJECT TERMINATION

no action

Date: FEBRUARY 2, 1977

Project Title: MICROEARTHQUAKE MONITORING, CARTER'S DAM, GEORGIA

Project No: G-35-612

Project Director: DR. L. T. LONG

Sponsor: U.S. ARMY; MOBILE DISTRICT, CORPS OF ENGINEERS; MOBILE, ALABAMA

Effective Termination Date: 12/31/76

Clearance of Accounting Charges: 12/31/76

Grant/Contract Closeout Actions Remaining:

X Final Invoice ~~and Closing Documents~~

_ Final Fiscal Report

_ Final Report of Inventions

_ Govt. Property Inventory & Related Certificate

_ Classified Material Certificate

_ Other ______________

is this in confidential? please check

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CA-4 (3/76)

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

July 16, 1974

Mr. Robert Dealy
Department of the Army
Mobil District, Corps of Engineers
P. O. Box 2288
Mobile, Alabama 36628

Subject: Quarterly Letter Report Number 1 covering period
March 6, 1974 to May 31, 1974

Reference: Contract No. DACW01-74-C-0077 Microearthquake Monitoring, Carters Dam Georgia.

Dear Sirs:

A portable seismic station has been operating Monday through Saturday with occasional down periods. During the total time period the instrument was recording an average of 55% of the time. Of this, 14% was noise leaving usable records for 41% of the total time period. During the critical period of loading a 95 to 100% of possible recording time would be desirable. The current recording time has been improved to about 80%. We intend to locate the instrument in the new visitors center as soon as practical. This move has been discussed with Mr. Joseph C. Blackman, Jr. We believe this site will be quieter and allow a reduction of the 14% of unusable noise records.

Nevertheless, the monitoring has recorded numerous quarry explosions and regional earthquakes. Both the Illinois event, April 3, 1974 and the Virginia event, May 30, 1974 were well recorded. Two events in the range of 50 to 80 km were also recorded and we are in the process of attempting to identify their source. We have recorded almost daily quarry explosions from 100 to 300 kilometers distant. Also, quarry explosions from a quarry 15 to 25 km from the dam have been recorded regularly. As these records indicate, we are getting significant high-gain records from the instrument.

Early in the recording period, tunnelling explosions were very well recorded. This activity, however, has stopped. Numerous smaller local sources of noise have been identified and probably include vehicle noise, as well as small rocks falling (or being thrown) near the seismometer. None of these small events have as yet been identified as a microearthquake. No significant microearthquake within a distance of 10 km was recorded during the period.

Respectfully submitted,

Dr. Leland Timothy Long
Project Director

LTL:gh

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES
Atlanta, Georgia 30332
(404) 894-2857

September 30, 1974

Lt. Col. William J. Wafer
Department of the Army
Mobil District, Corps of Engineers
P. O. Box 2288
Mobile, Alabama 36628

Subject: Quarterly Letter Report Number 2 covering period June 1, 1974 to August 31, 1974

Reference: Contract No. DACW01-74-C-0077
Microearthquake Monitoring, Carters Dam, Georgia

Dear Sirs:

A portable seismic station has been operating Monday through Saturday with occasional down periods. During the period June 1, 1974 to August 31, 1974 the instrument recorded an average of 49% of the total available time. This corresponds to 67% for June, 42% for July and 38% for August. Of this recorded time, less than 8% was noise leaving usable records for 46% of the total time period. This amounts to a slight improvement over the 41% reported for the previous quarter. However, the down time in July and August were due largely to difficulties in maintaining a charge on the batteries. The instrument and batteries were changed in August. Also, a new instrument is under construction and should be available for placement by the end of October, provided it is practical to place it in the visitors center at that time.

The monitoring has recorded numerous quarry explosions and regional earthquakes. Over twenty events in the distance range of 150 to 300 km were recorded. These are probably large explosions used in mining. Three events were identified in the 30 to 50 kilometer distance range. We are still attempting to locate these events but believe they are also quarry explosions. The records regularly record quarry explosions from a quarry 15 to 20 km from the dam site. As these records indicate, we are getting significant high-gain records from the instrument.

Some local noise sources have been identified and include vehicle noise or small rocks falling (or being thrown) near the seismometer. No significant microearthquake activity has been identified within a distance of 10 km during the quarter.

Respectfully submitted,

Dr. Leland Timothy Long
Project Director

LTL:gh

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

January 24, 1975

Lt. Col. William J. Wafer
Department of the Army
Mobile District, Corps of Engineers
P.O. Box 2288
Mobile, Alabama 36628

Subject: Quarterly Letter Report Number 3 covering period of September 1, 1974 to November 31, 1974

Reference: Contract No. DACW01-74-C-0077, Microearthquake Monitoring, Carters Dam, Georgia

Dear Sirs:

A portable seismic station has been operating Monday through Saturday with occasional down periods. During the period September 1,1974 to December 31, 1974, the instrument recorded an average of 46% of the total available time. This corresponds to 34% for September, 46% for October and 57% for November. Of this recorded time, less than 8% was noise leaving usable records for 38% of the total time period. This amounts to a decrease from the 46% reported for the previous quarter. On the 8th of December, 1974, a new semi-permanent instrument was installed at a location which should provide greater isolation from non-seismic noise sources.

The monitoring has recorded numerous quarry explosions and regional earthquakes. These include the South Carolina earthquake (m_b = 4.5) of November 21, 1974 near Summerville and events near the Clark Hill Reservoir. The records regularly record quarry explosions from a quarry 15 to 20 km from the dam site. This quarry(s) has not been located positively as yet. As the records indicate, we are getting significant high-gain records from the instrument.

Some local noise sources have been identified and include vehicle noise or other local sources. Two isolated events with characteristics of a small explosion within a few thousand feet were identified in September. Their singular occurrence and character were not typical of microearthquakes. Otherwise, no significant microearthquake activity has been identified within a distance of 10 km during the quarter.

Respectfully submitted,

Dr. Leland Timothy Long
Project Director

LTL:bh

G-35-612

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

June 3, 1975

Lt. Col. William J. Wafer
Department of the Army
Mobile District, Corps of Engineers
P.O. Box 2288
Mobile, Alabama 36628

Subject: Quarterly Letter Report Number 5 covering period of 1 March 1975 to 31 May 1975

Reference: Contract No. DACW01-74-C-0077, Microearthquake Monitoring, Carters Dam, Georgia

Dear Sirs:

A seismic station has been operating Monday through Saturday during normal work weeks. Occasional time was lost because of occasional instrument malfunction, related primarily to the ink system installed for convenience. During the period of 1 March to 31 May 1975 the instrument was recording an average of 47% of the total available time. This corresponds to 37% for March, 48% for April and 57% for May. Of this recording time, less than 7% was noise leaving usable records for 40% of the total time period. The maximum time coverage without weekend record changes would be about 70%. During the quarter the monitoring has recorded numerous quarry explosions and a few regional earthquakes. The M_L = 6.3 Idaho earthquake of 27 March recorded a P-phase at 02:36:14.1 GMT. The quarry activity at about 20 km continued to be recorded. Over 20, probably quarry, events in the distance range of 50 to 300 km were also recorded. Local noise sources have also been identified and include vehicles, thunder and possibly motorboats. No microearthquakes could be identified positively, if there were any during the recording period their amplitudes were below the noise level. No significant microearthquake activity has been identified within a distance of 10 km during the period.

At the end of the period, 25 May 1975 the seismograph was moved into the display room of the visitors center. We hope that when it is open to the public on Saturdays we can arrange for continuous recording. Some of the problems related to pen stoppage may be caused by the inactive periods during the weekends.

Respectively submitted,

Leland Timothy Long
Associate Professor of Geophysics

LTL:bh

G-35-612

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

September 9, 1975

Lt. Col. William J. Wafer
Department of the Army
Mobile District, Corps of Engineers
P. O. Box 2288
Mobile, Alabama 36628

Subject: Quarterly Letter Report Number 6 covering period of June 1, 1975 to August 31, 1975.

Reference: Contract No. DACW01-74-C-0077, Microearthquake Monitoring, Carters Dam, Georgia.

Dear Sirs:

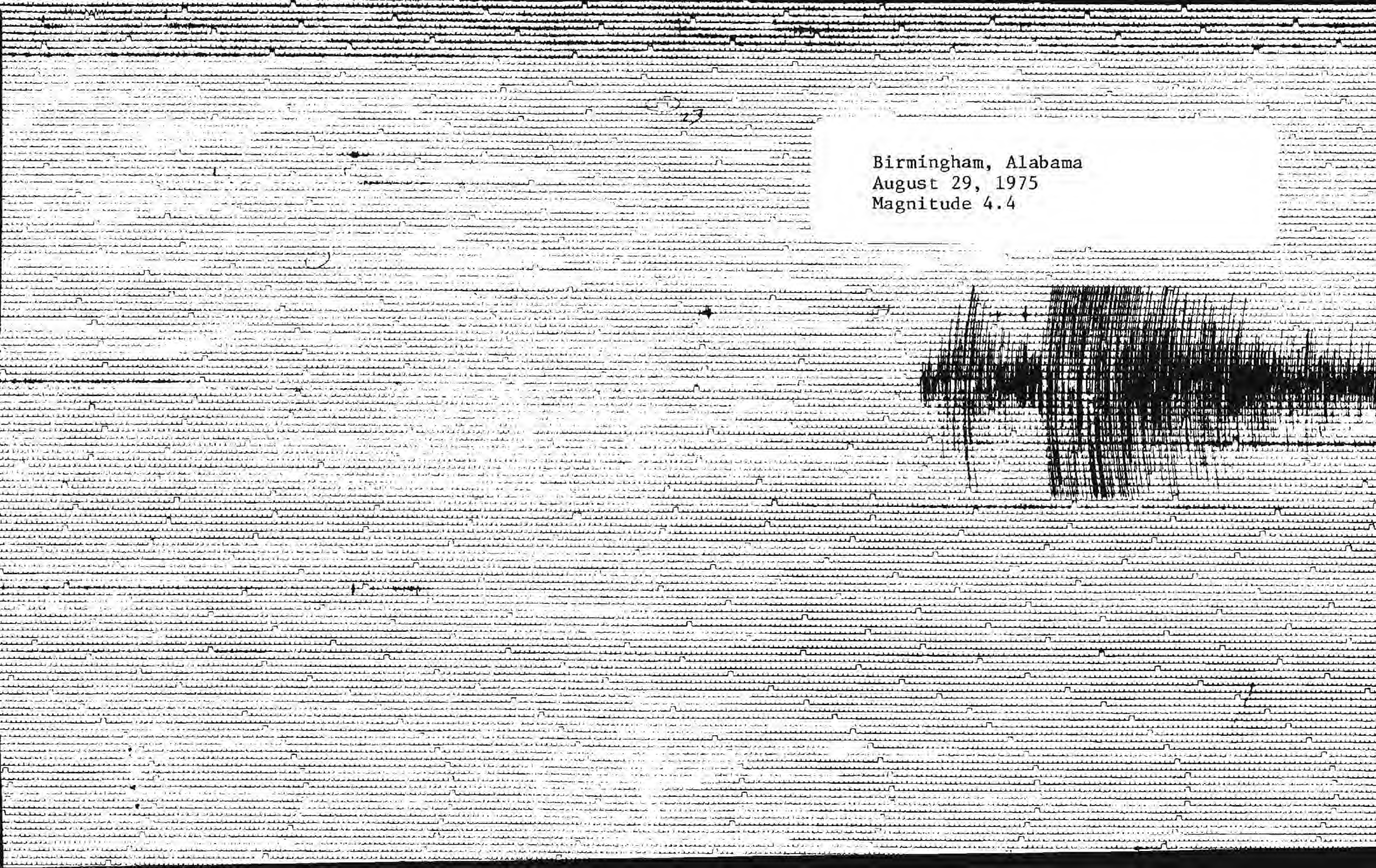
A seismic station has been operating Monday through Saturday during normal workweeks. Occasional time was lost due to instrument malfunctions, related largely to the ink system. During the period of 1 June to 31 August 1975 the instrument was recording an average of 48% of the total available time. This corresponds to 70% for June, 36% for July and 39% for August. Of this recording time an insignificant 1% was obscured by noise consisting mostly of thunderstorms. The maximum time coverage without weekend record changes would be about 70%.

In July the response of the system was modified to allow recording at higher gain. Spectral analysis of the background noise indicated that most of the interfering background noise was of local origin and in the frequency range of 30-50 Hz. The new response filters out much of this noise without hindering the recording capabilities for local events. The improved gain at lower frequencies (1-20 Hz) make this station as good as or better than most seismic stations in the southeast for recording regional earthquakes. When the recording instruments are run at maximum practical gain as many as eight or ten quarry explosions or seismic events in the distance range of 100-250 km are recorded per day. Of particular interest is the recording of the Birmingham, Alabama (copy enclosed) magnitude 4.4 earthquake and a couple of its possible foreshocks.

No microearthquakes could be identified positively. If there were any during the recording period their amplitudes were below the noise level. Some irregular signals of local origin were observed and attributed to stones rolling (or being thrown) down the slope or limbs falling out of the trees. No significant microearthquake activity has been identified within a distance of 10 km during the period.

Respectfully submitted,

Leland Timothy Long



Birmingham, Alabama
August 29, 1975
Magnitude 4.4

G-35-612

GEORGIA INSTITUTE OF TECHNOLOGY

SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

December 11, 1975

Lt. Col. Donald R. Pope
Department of the Army
Mobile District, Corps of Engineers
P.O. Box 2288
Mobile, Alabama 36628

Subject: Quarterly Letter Report Number 7 covering period of 1 September 1975 to 30 November 1975.

Reference: Contract No. DACW01-74-C-0077, Microearthquake Monitoring, Carters Dam, Georgia.

Dear Sirs:

The Carters Dam seismic station has been operating Monday through Saturday during normal work weeks. Occasional time was lost due to instrument malfunctions, largely related to the ink system. During the period of 1 September 1975 to 30 November 1975 the instrument was recording an average of 39% of the total available time. This corresponds to 29% for September 46% for October and 42.6% for November. Of the total recording time only 2% was obscured by noise. The maximum time coverage without weekend recording changes would be about 70%.

The copy of the record attached is of particular interest since it shows the recording of an earthquake which occurred at Jacossee Dam, South Carolina. The Jacossee Dam is similar in many respects (depth and size of reservoir) to Carters Dam. This earthquake occurred approximately two years after filling of the reservoir. Georgia Tech is participating in the monitoring of the activity at Jacossee Dam and will thus have access to all data relavent to the occurrence of those events. This should help in the identification and evaluation of events in the vicinity of Carters Dam, Georgia. In addition the record shows the typical response of the records to events in the 100 to 300 km range. The particular event was about 210 km distant from Carters Dam and was probably a quarry explosion equivalent to 10,000 to 20,000 lb. TNT.

Finally this record shows typical examples of some unidentified local signature which has started showing up on the records in the last two to three months. Initially these have been attributed to things like nuts falling from trees or some similar mechanism. Their character is not like what is expected from a local event. However, if they continue at a regular rate we will carry out a local survey to determine their exact origin.

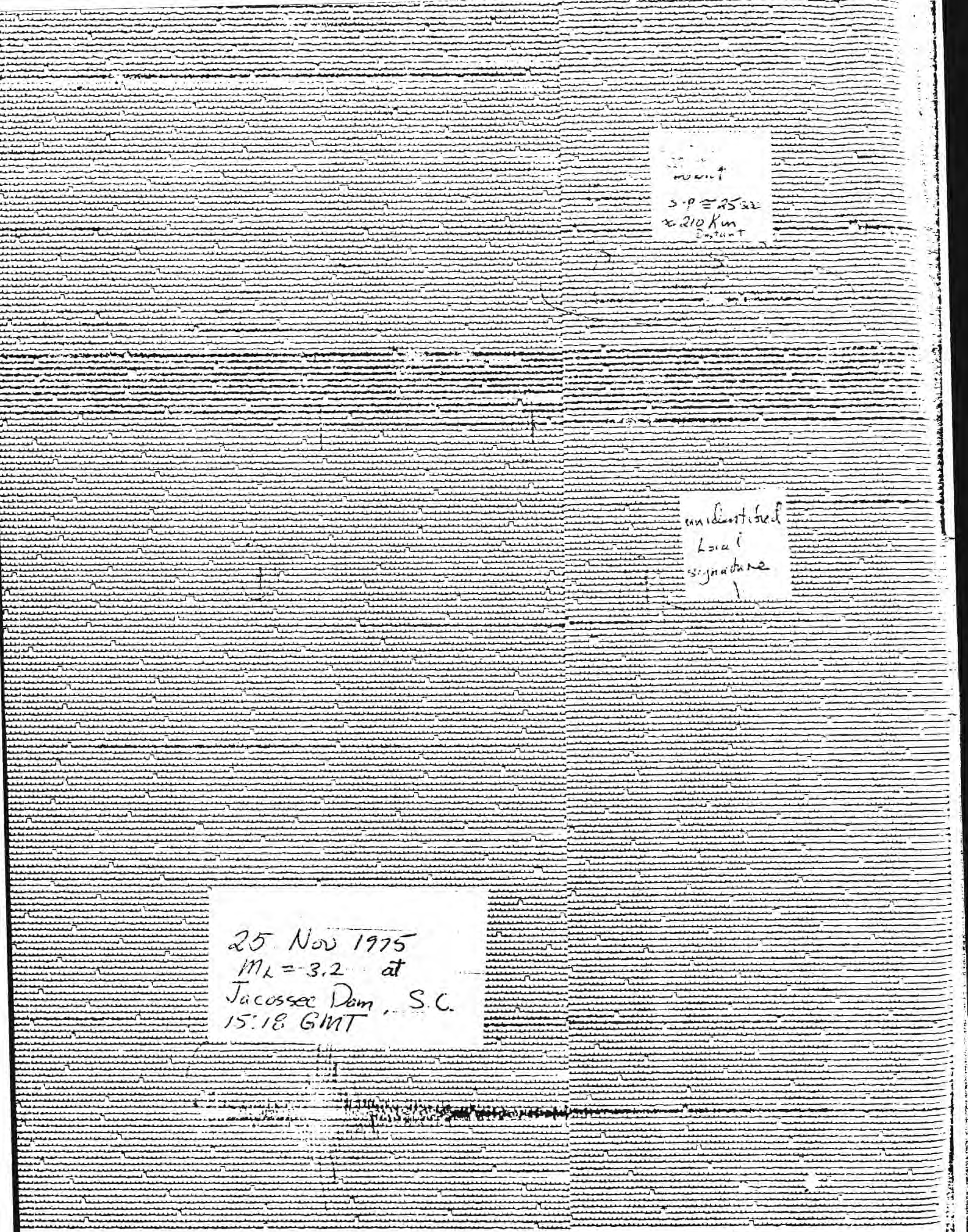
No microearthquakes could be identifies positively. If there were any during the recording period their amplitudes were below the noise level. No seismic activity has been identified within a distance of 10 km during the period.

Respectfully submitted.

Leland Timothy Long
Associate Professor
Geophysical Sciences

LTL:jg

Enclosed: Carters Dam record 24-25 Nov. 1975



S-P ≅ 25 sec
≈ 210 Km
Distant
unidentified
Local
signature
25 Nov 1975
$M_L = 3.2$ at
Jacossee Dam, S.C.
15:18 GMT

G-35-612

GEORGIA INSTITUTE OF TECHNOLOGY

SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

March 25, 1976

Lt. Col. Donald R. Pope
Department of the Army
Mobile District, Corps of Engineers
P.O. Box 2288
Mobile, Alabama 36628

ERTA

Subject: Quarterly Letter Report Number 8 covering period of 1 December 1975 to 29 February 1976.

Reference: Contract No. DACW01-74-C-0077, Microearthquake Monitoring, Carters Dam, Georgia.

Dear Sirs:

Enclosed is page 18 of report Number 8 which was inadvertently omitted from the copies sent to you on March 23, 1976. Please include these pages in the appropriate place.

We regret any inconvenience caused by this oversight on our part.

Sincerely,

Leland Timothy Long
School of Geophysical Sciences

LTL:jg

G-35-612

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

March 22, 1976

Lt. Col. Donald R. Pope
Department of the Army
Mobile District, Corps of Engineers
P.O. Box 2288
Mobile, Alabama 36628

Subject: Quarterly Letter Report Number 8 covering period of 1 December 1975 to 29 February 1976.

Reference: Contract No. DACW01-74-C-0077, Microearthquake Monitoring, Carters Dam, Georgia.

Dear Sirs:

The Carters Dam seismic station has been operating Monday through Saturday during normal work weeks. Occasional time was lost due to instrument malfunctions, largely related to the ink system. During the period of December 1975 to 29 February 1976 the instrument was recording an average of 62.5% of the total available time. This corresponds to 69% for December, 48% for January and 71% for February. Of the total recording time only 3% was obscured by noise. The maximum time coverage without weekend record changes would be about 70%.

The Quarry explosion that has shown up regularly on the Carters Dam records with an S-P of 2.0 to 2.4 seconds appears to coincide with the Whitestone Crushed Stone Operation approximately 16 km to the southeast of Carters Dam. The seismograms continued to show evidence of other industrial quarry activity at greater distances.

The low-frequency background noise in the range 3 to 5 seconds is unusually high at times when a weather front crosses the reservoir. This noise is probably related to winds and waves which are weather generated.

The Carters Dam station recorded the larger events occurring near Jocassee Dam in South Carolina. The author has had the opportunity to oversee some of the work and data associated with the Jocassee earthquakes. Largely because of this experience a set of recommendations has been prepared and they are attached to this letter.

As a response to a request from David M. Patrick, Waterways Exp. Station, a general description of the instrumentation and monitoring program was prepared. A revised version is attached to this report.

During the period the unidentified local signature continued to occur at all hours. They are identified tentatively as the result of objects falling from trees near the seismometer. For the most part their character does not allow the identification of the usual S and P phase with appropriate decay for the implied distance to the event. However, on

December 18, 1975, two signatures and a number of smaller ones on preceeding days showed the character appropriate for an (S-P) time of 1 sec (i.e. less than eight kilometers) and lack of evidence for any surface phases. These may have been microearthquakes. If they were microearthquakes their magnitude would be less than 0.

Of particular interest was the recording of an earthquake located southeast of Dalton, Georgia on 4 February 1976. The event was a magnitude (M_L) 3.2 event and it occurred approximately 36 km east-northeast of the Carters Dam seismic station. Many aftershocks and foreshocks were recorded on the Carters Dam seismometer. Georgia Tech set up portable seismometers in an attempt to locate aftershocks and learn more about the Dalton, Georgia earthquake. A preliminary version of a report on the earthquake is attached. The Carters Dam station provided exceptional data for this study.

With the exception of the signatures noted above, no microearthquakes could be identified positively as occurring within 10 km of Carters Dam during the period of this report. If there were any local events during the report period, their amplitudes were below the noise level or they occurred while the instrument was not recording. The Dalton, Georgia earthquakes have occurred no closer than 25 km from Carters Dam.

Respectfully submitted,

Leland Timothy Long
Associate Professor
School of Geophysical Sciences

LTL:jg

Enclosures

Reference: "Microearthquake Monitoring, Carters Dam, Georgia" Contract No. DACW01-74-C-0077, U.S. Army, Corps of Engineers, Mobile District.

Title: General Description of Seismic Monitoring at Carters Dam, Ga.

Author: Dr. Leland Timothy Long

Date: 10 February 1974 (Revised 5 March 1976)

Purpose. Earthquake activity occurring in the vicinity of reservoirs usually consists of a foreshock sequence with an increasing rate of activity, a main event or sequence of main events, and an aftershock sequence. The duration of a total sequence which involves a significant magnitude 4.0 or larger event is typically in excess of a few months. Consequently, prediction of the main event of the sequence may be possible if instrumentation capable of recording the smaller foreshocks can be installed early in the sequence. The purpose of seismic monitoring at Carters Dam is to detect and identify local microearthquakes (if any) and to determine if there is any association between filling of the reservoir and the occurrence of the microearthquakes near Carters Dam.

Instrumentation. The recorder is located in the visitor's center above Carters Dam. The recorder is a helical drum recorder utalizing an ink writing system. The recording speed is 60 mm/min and the translation rate allows one day of recording for each record. The amplifier is a 6 db per step grain dc amplifier with a high-frequency (6db/octabe) cut off now set at a 3 db point at 10 Hz. The system is capable of a flat response up to 80 Hz but local noise above 30 Hz seriously decreases the sensitivity of the system when used without the low-pass filter. The system was designed and assembled at Georgia Tech.

The system is powered by an 110V ac to dc ($\pm$ 12V) regulated power supply and contains internal batteries capable of maintaining operation during temporary power outages. Time control is provided by a Sprengnether temperature-compensated crystal timing system housed in a seperate container. A WWV receiver is in the unit for correcting the time to Universal time. The seismometer is located approximately 500 ft northwest of the recorder to isolate it from noise sources. The seismomemter is a 1.0 Hz Geospace instrument with a 500 KΩ coil. A low-power battery operated pre-amplifier was built into the seismometer by Georgia Tech to increase the signal level, reduce the line impedence and suppress extranious noise. The seismometer is housed in a weather-tight container mounted on a cememt pad. The cement pad is dug into the ground approximately two feet.

Record keeping and interpretation. At Carters Dam the recording paper is changed Monday through Friday by Corps of Engineer personnel to provide 5 days of recording time each week. Ideally, the records should be changed 7 days a week. The seismograms are mailed weekly to Georgia Tech. When received, the seismograms are examined for evidence of local (i.e less than 15 km) seismic activity. Other events which occur at distances greater than 15 km are catalogued for reference and identification. All unusual events are examined and catalogued. Once every three months, a short letter report is prepared to show the recording time and activity levels during the period. If local activity is identified a report will be submitted as soon as possible.

Subject: Recommendations for seismic monitoring of seismic activity associated with reservoirs

Author: Dr. Leland Timothy Long, School of Geophysical Sciences
Georgia Tech, Atlanta, Ga. 30332

Reference: Possible action by Georgia Tech should activity be detected at Carters Dam through microearthquake monitoring activities covered by Contract No. DACW01- 74 - C - 0077.

Reasons for Report: The author has recently had the opportunity to review the data and its analysis for earthquake activity associated with Jocassee Dam in South Carolina. A summary of the program including problems encountered and the more successful techniques utilized might be helpful in formulating plans for action at Carters Dam or other reservoirs associated with seismic activity. Also, on February 4, 1976, 19:59:UT, a magnitude 3.0 earthquake occurred approximately 40 km from the Carters Dam Seismic station. This event was beyond a distance for immediate concern at Carters Dam. However, we did wish to investigate it more closely. The rush of activities that followed made us realize that should an event occur near Carters Dam we would have little time to prepare recommendations of action for the Corps of Engineers to follow. Hence, these recommendations are being prepared in advance.

Recommendations: The following recommendations are based largely on recent experiences at Jocassee Dam in South Carolina and on Georgia Tech's establishment of a net in the Clark Hill Reservoir area. Jocassee Dam is similar to Carters Dam in elevation and height. However, Carters is insulated from basement crystalline rocks by some thickness of sedimentary and metamorphic rocks. In my current opinion, much of the seismic activity observed in the southeast is related to the more rigid features of the crust. The surface rocks play a secondary role in any seismic activity that might occur. In the case of Jocassee, the crystaline rocks are near the surface and most of the earthquakes are at depths less than 2.0 km. I believe significant activity at Carters Dam would in contrast be at depths 1 to 3 km or if shallower, in the harder rocks to the east of the Dam. If earthquakes are to be triggered by changes in pore pressure, then additional time might be required for the changes in water pressures to penetrate the surface sedimentary and metamorphic rocks. At Jocassee, in comparison, the activity initiated about 1-3 yr after filling. If there is stress in the rock which might be released by a change in pore pressure at Carter's then activity might be delayed two or more years.

A. The first recommendation is that all reservoirs establish a monitoring system for simple detection of local events. Ideally, the system should be operated continuously starting at least 1 year before filling of the reservoir and continuing as long as the reservoir exists. While most activity occurs during or just after loading, continued operation would provide valuable regional seismic data. Monitoring at Jocassee was not initiated until an earthquake was felt locally and identified by local seismologist. Potentially valuable information on foreshock activity may have been lost. The type of instrument recommended would be a short-period vertical seismometer recorded on a helical drum recorder with timing precision of 0.1 sec or better. This is the type of instrument currently in operation at Carters Dam. However, the recording site does not have to be at the Dam Site since telemetry systems can provide similar quality data recorded at distance. Georgia Tech currently has two operational systems which use telephone telemetry to record in Atlanta data from the Clark Hill Reservoir area. Recording at Georgia Tech makes it easier to maintain continuous records. A similar system could be installed at Carters Dam for recording at Georgia Tech to reduce personal involvement at Carters Dam and obtain seven days of data each week but there would be a monthly phone line charge.

B. The second reccomendation is that if activity is identified, seismic monitoring should be achieved with an array consisting of 3 to 5 portable microearthquake recorders. This would be short term and the primary objective would be to locate the activity and provide a more accurate measure of the level of activity. Should activity be detected at Carters Dam, Georgia Tech would investigate with portable recorders. The short-term investigations would probably be partially supported by other grants in effect at Georgia Tech. The results of these studies could be used to help decide whether long-term multi-station monitoring should be initiated to obtain the quality and amount of data necessary for prediction.

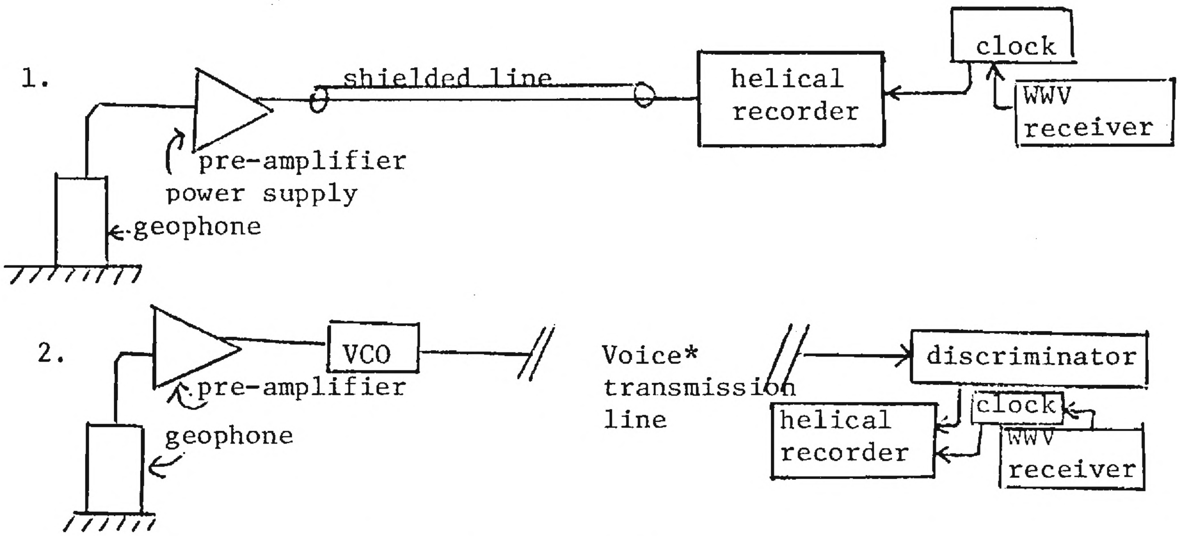
C. The third recommendation is that if long-term (i.e greater than 6 mo.) recording is advised, this should be achieved with a centrally recorded net. The initial expense may seem objectionable, particularly when considering the hope that the monitoring will be short term. The advantages in the quality and consistancy of the data far outweigh any savings realized in using portable units. In particular, the use of a single time reference eliminates errors introduced by attempts to syncronize at least six clocks to within ± 0.02 seconds. Also, there is no delay in obtaining data from the field and there is a closer control on the quality of the data. With a monitoring program using about 6 centrally recorded stations, one objective would be the measurement of possible earthquake predictors. For example, to use the ratio V_p/V_s effectively as a predictor the data must be precise and a base line must be known. For timely prediction the data should be available for analysis within two days if not immediately. In contrast, the portable systems used at Jocassee require two field technicians vitually full time and there is an inherent two to four day delay in examining the data. Also, while the multiple-organization analysis arrangements may be unusual at Jocassee, the use of copies of smoked paper records imposed on one organization is unacceptable if quality results are required. The results of Long-term monitoring would include activity levels, b values, hypocenters, focal plane solutions and possibly V_p/V_s ratios. This data, combined with a study of the local geology could be used to evaluate the significance of the seismic activity and indicate whether continued detailed monitoring is advisable. In particular this data could be used to estimate the maximum earthquake to be expected and thus allow evaluation of the response of the structure to such an earthquake.

Instrument Systems Compatable with Reccomendations

A.

1.

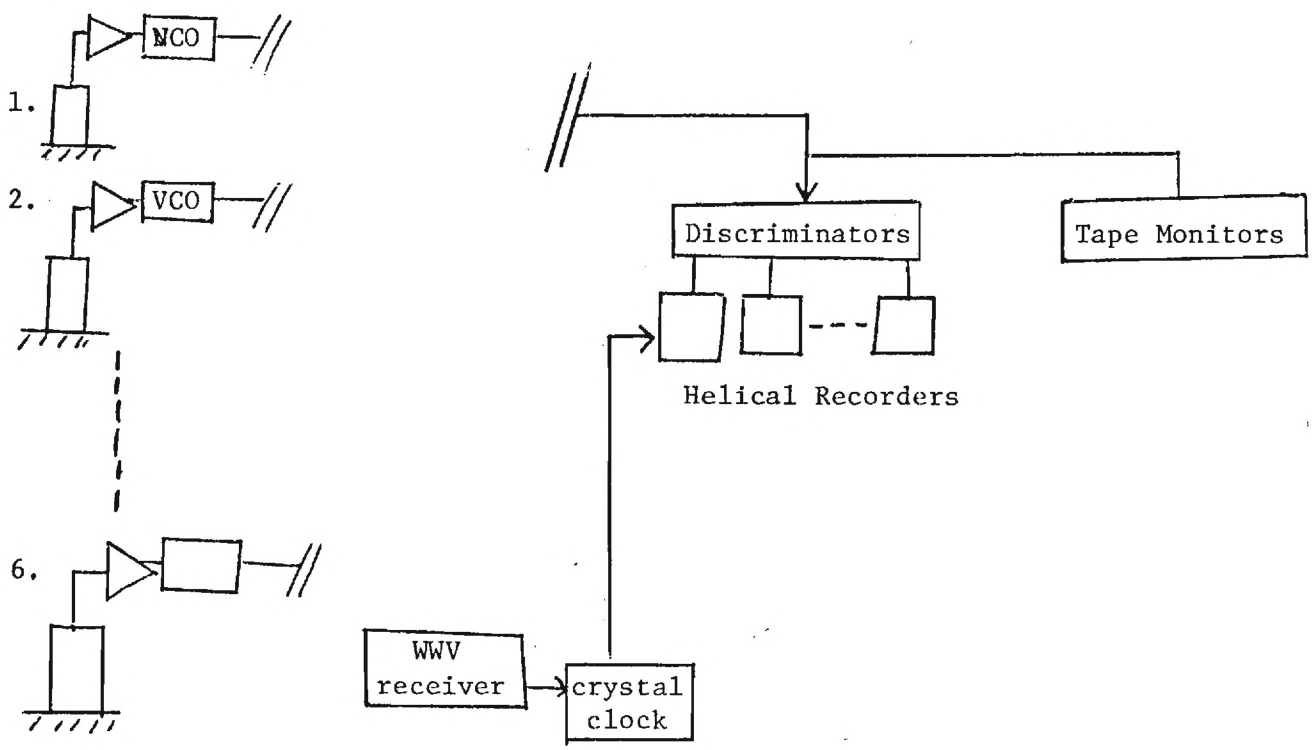
2.



*note: if one channel is used the dynamic range is significantly greater than if 6 are multiplexed on oreline

B. Any commercial helical smoked paper recorder or portable tape recorder

C.



THE DALTON, GEORGIA, EARTHQUAKE OF FEBRUARY 4, 1976

by

Leland Timothy Long

and

Stewart A. Guinn

March 10, 1976

"PRELIMINARY REPORT"

note: This report includes only data obtained prior to February 29, 1976

The analysis of this data is not complete.

Do not quote without permission of the authors

Research supported by the Earth Sciences Section, National Science Foundation,

NSF Grant DES75-15756

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THE DALTON EARTHQUAKE OF FEBRUARY 4, 1976

I. INTRODUCTION

On February 4, 1976 at 19:53:55 Universal Time (2:53 E.S.T.) an earthquake of magnitude M_L = 3.1 as determined from the ATL Station seismograms occurred east-southeast of Dalton, Georgia. The epicenter was estimated to be $34^{o}45'$ N and $84^{o}52'$ W $\pm$ 3 km. The epicenter was determined largely by seismic records from CDG (Carters Dam) and aftershocks recorded on portable instruments. The epicenter was about 30 km northwest of the Carters Dam Station. Twenty-one foreshocks and aftershocks have been detected on the Carters Dam seismograms. Additional microearthquakes were recorded in an aftershock survey following the main event.

The object of this report is to assemble data obtained prior to March 1, 1976 and develop preliminary conclusions concerning the occurrence of the Dalton, Georgia Earthquakes.

II MAIN EVENT

A. MACROSEISMIC DATA: The earthquake of February 4, 1976 was felt throughout northwest Georgia within a radius of about 30 km centered about Dalton. Felt reports were also obtained from areas west and northwest of Chattanooga, Tennessee. Several employees from a Dalton bank reported that they heard what sounded like a sonic boom. Another reported that the bank building shook a little. The duration was on the order of a few seconds. Also an employee sitting near one of the walls reported the wall pulsated. No damage has yet been reported. The maximum intensity was about III MM and the total felt area was about 2800 sq. km. Results from the U.S. Geological Survey postcard intensity survey are not known at this time.

B. INSTRUMENTAL DATA: The February 4, 1976 event was recorded at a number of southeastern United States seismic stations. The interpretations of these records is given in Table 1.

III GEOLOGY OF DALTON AREA

A. INTRODUCTION: The epicentral area is located in the Valley and Ridge province of northwest Georgia. The surface geology within this area consists of Lower-Paleozoic sedimentary rocks ranging from Cambrian to Ordivician in age. The rock types are limestone, shale, and sandstone sequences which have been folded and thrust faulted along a trend of N 15^{o} E. The topography of the area consists of moderate to low rolling hi-ls ranging in elevation from 600' to 800' above sea level. The area contains several anticlines and synclines trending N 15^{o} E and dip to the southeast. Several small normal faults appear with a NW strike. The proposed epicenter lies in the mid-southwestern portion of the Dalton quadrangle. The area contains a well developed drainage system which is structurally controlled by faults, synclines, and anticlines. The major streams within the epicentral area are Mill Creek, Coahulla Creek and the Conasauga River.

B. LITHOLOGIES: The rock types exposed within the epicentral area are from oldest to youngest; the Cambrian Rome shale and sandstone, the Cambrian Conasauga shale and limestone, the Ordivician-Cambrian Knox dolomite, and Quaternery alluvium. The above named formations are underlain by the Shady dolomite of Cambrian age and the Weisner quartzite also of Cambrian age at the base. Depth to basement in this area is unknown but may be in excess of 10,000 ft. Topography in the area is controlled primarily by resistance to erosion. The Knox dolomite and Rome shale and sandstone from the ridges and the Conasauga shale forms the valleys.

C. FAULTS WITHIN AREA: Munyan's (1951) Geologic Map of the Dalton quadrangle, (Figure 1) shows going from East to West, possibly 3 major thrusts faults, in the epicentral area. (Figure 1) Two major thrusts (the Varnell and Rome) strike from N to NE through downtown Dalton. The upthrust side is to the east. A third possible thrust (Coahulla fault) with a similar trend runs through the epicentral area. Uncertainity as to the location of the Coahulla fault comes from the lack of exposure mainly due to alluvial cover. This fault is defined fairly well to the north. Coahulla Creek flows parallel to the fault trace. Further to the east several more thrust faults are shown. Figure 2 shows a cross-section taken from Butt's geologic map of Georgia which is in essential agreement with Munyan's (1951) interpretation shown in Figure 8.

Munyan (Figure 1) also shows two normal faults several miles north of the epicentral area. These faults cut across the regional structure and strike to SW. Smaller scale faulting within the area has been noted.

IV CARTERS DAM RECORDS

The Carters Dam Station (DCG) is located approximately 30 kilometers from the epicentral zone. Twenty-one events have been identified on CDG as having S-P and character consistent with the February 4, 1976 event. These events are listed in Table 2. The Carters Dam Station is normally operated from Monday morning to Saturday afternoon. Hence the data may not be complete. The station gain settling for all events was 30 db which is equivalent to a displacement gain of 80 k at 10 Hz. Reliable first motions at CDG indicate an upward ground motion in all cases except for two events. The main event recorded at CDG is shown in Figure 3.

A significant variation in S-P times was observed at CDG. Figure 4 shows the distribution of these S-P times. Most are centered about 4.3 sec. with a range from 3.0 to 4.5 secs. Events with S-P values of, 4.7, 4.8, 5.1 (2 events) and 5.5 sec. were also observed.

TABLE 1

Regional Seismic Arrivals for the Dalton, Ga., earthquake of February 4, 1975

Station	Phase and Arrival Time	
CDG	PC-19:54:01	S 19:54:05.5
CPO	PC-19:54:11.3*	(:11.1) from original record
ORT	PD-19:54:30.5	P 19:54:31.2
CH6	Pn-19:54:30.5	P 19:54:31.2
CH5	P-19:54:33.5	
WCK	P-19:54:54.9*	
ELC	P-19:55:00.4*	
DON	P-19:55:05.9	
RMB	P-19:55:07.6*	
BLA	Pg-19:55:11.0*	
AMG	Lg-19:55:26 ?	
JSC	requested but not received	
ATL	PC-19:54:21.3	S 19:54:41.3 (Amp = 10mm) $M_{LGSE} = 3.1$
"	P2-19:54:23	S2-19:54:44 (Amp SH = 14mm)
GSC	PD-19:54:21.5	

* times furnished by the U.S. Geological Survey

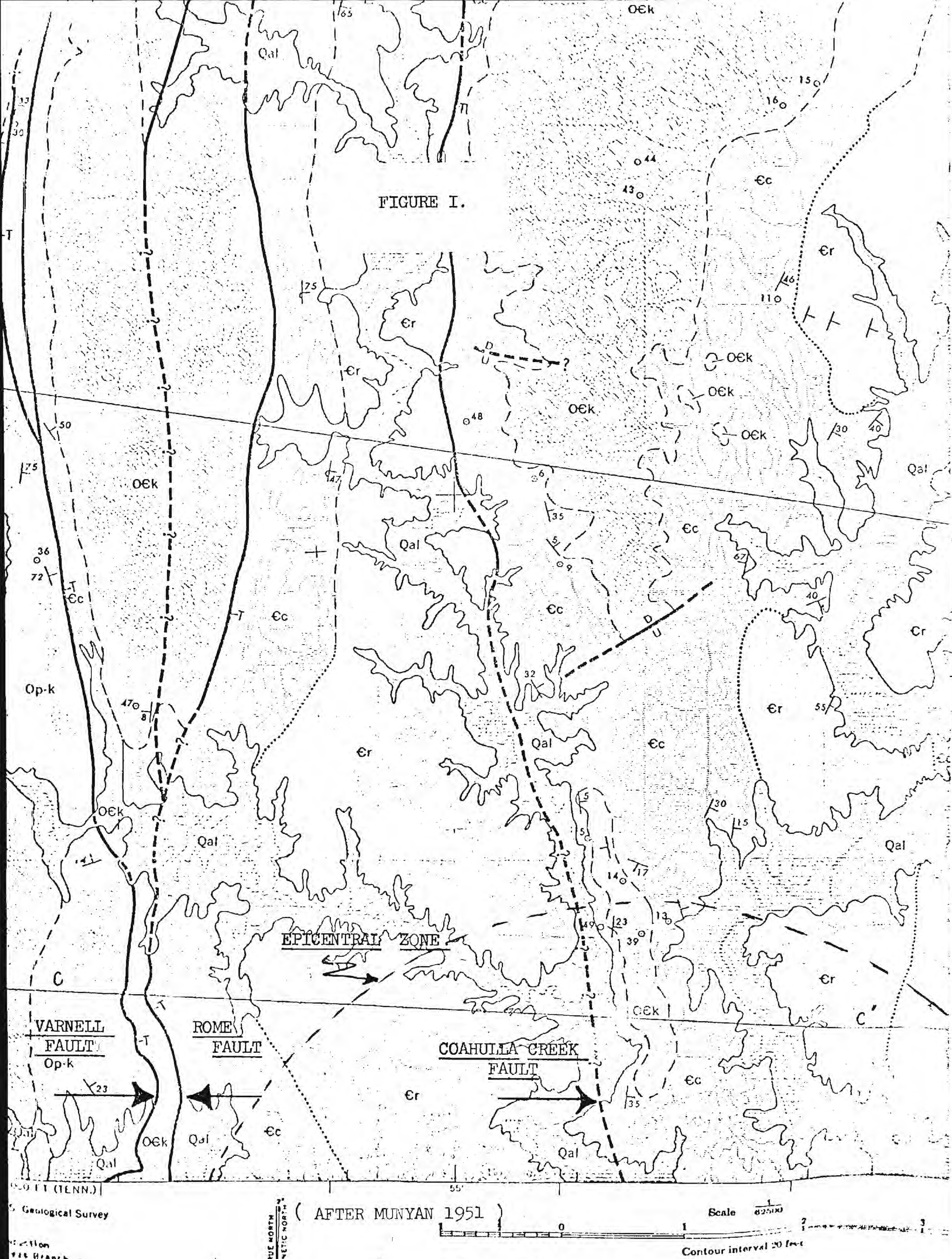


FIGURE I.
EPICENTRAL ZONE
VARNELL FAULT
ROME FAULT
COAHULLA CREEK FAULT
(AFTER MUNYAN 1951)
Geological Survey
Scale
Contour interval 20 feet
TRUE NORTH
MAGNETIC NORTH

If one fault is responsible for this activity then the lower the range of S-P times given above indicates a length greater than 5 km for the active part of the fault. If the more distant events are on the same fault then the total active length may be greater than 12 km.

An S-P versus time curve (Figure 5) was plotted to see if there were any consistent changes with time of the epicenters. The events with S-P times of 5.1 and 5.5 sec. appear anomalous. It should be noted from (Figure 5) that there is a marked increase in the number of events leading up to the main event.

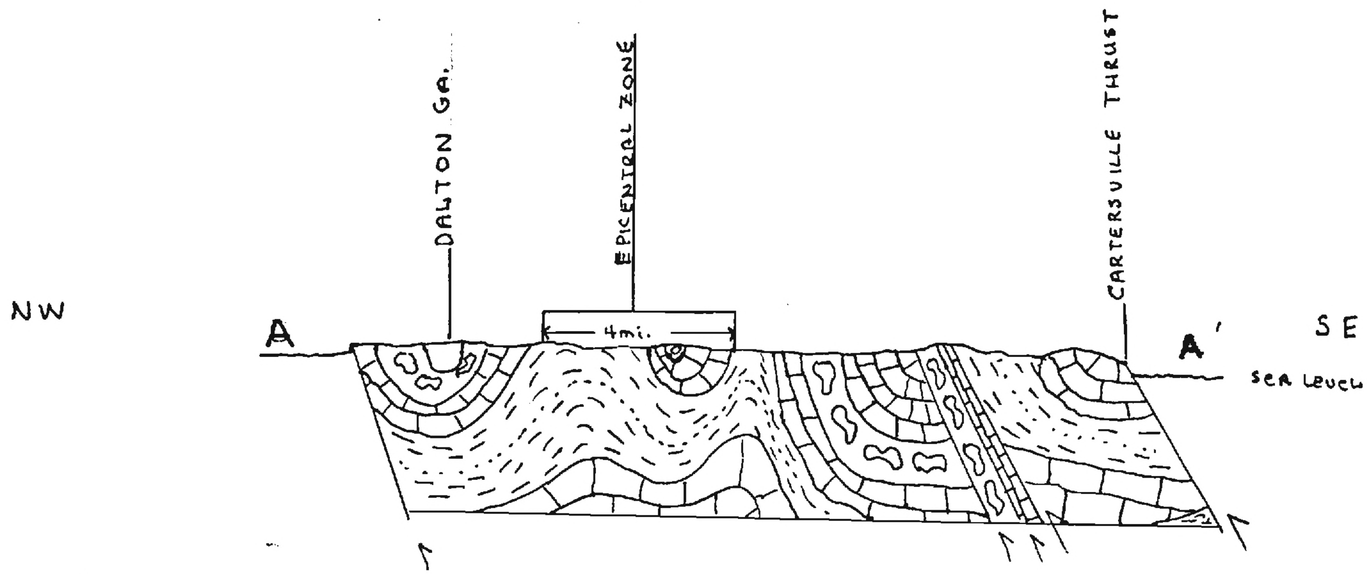
During the time from November 1975 to the main shock on February 4, 1975 the S-P times appeared to migrate from around 4.1 to 4.5 ($\pm$ 0.2 sec). The last two events continue this trend (4.5 and 4.8 seconds).

The recursion relation shown in (Figure 6) indicates a "b" value of -0.8. The recursion relation was computed from the assumption that the Log of the S-wave amplitude was proportional to the local magnitude. The "b" value of -0.8 is lower than generally observed in the Southeast United States but consistent with "b" values from other seismic areas.

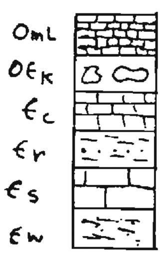
V AFTERSHOCK MONITORING

On February 10, 1976 through February 12, 1976 portable microearthquake recording sites were established to record possible aftershocks of the main event of February 4, 1976. Also, on February 12, 1976 through February 15, 1976 and February 20, 1976 through February 22, 1976 portable microearthquake recorders were used in a field survey for aftershocks. The trip number, recording dates, number of hours of recording, locations, etc. are given in Table 3. The results of these trips are discussed below.

Trip No. 1 involved taking two smoked paper monitors to areas near Mount Vernon, Georgia and Varnel, Georgia. The smoked paper monitors re-



EXPLANATION

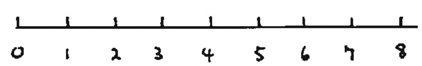


GEOLOGIC CROSSECTION THROUGH EPICENTER

FROM GEOLOGIC MAP OF NW GEORGIA

BY BUTTS

H. SCALE



MILES

1" ≃ 4 miles

1" ≅ 6.4 km

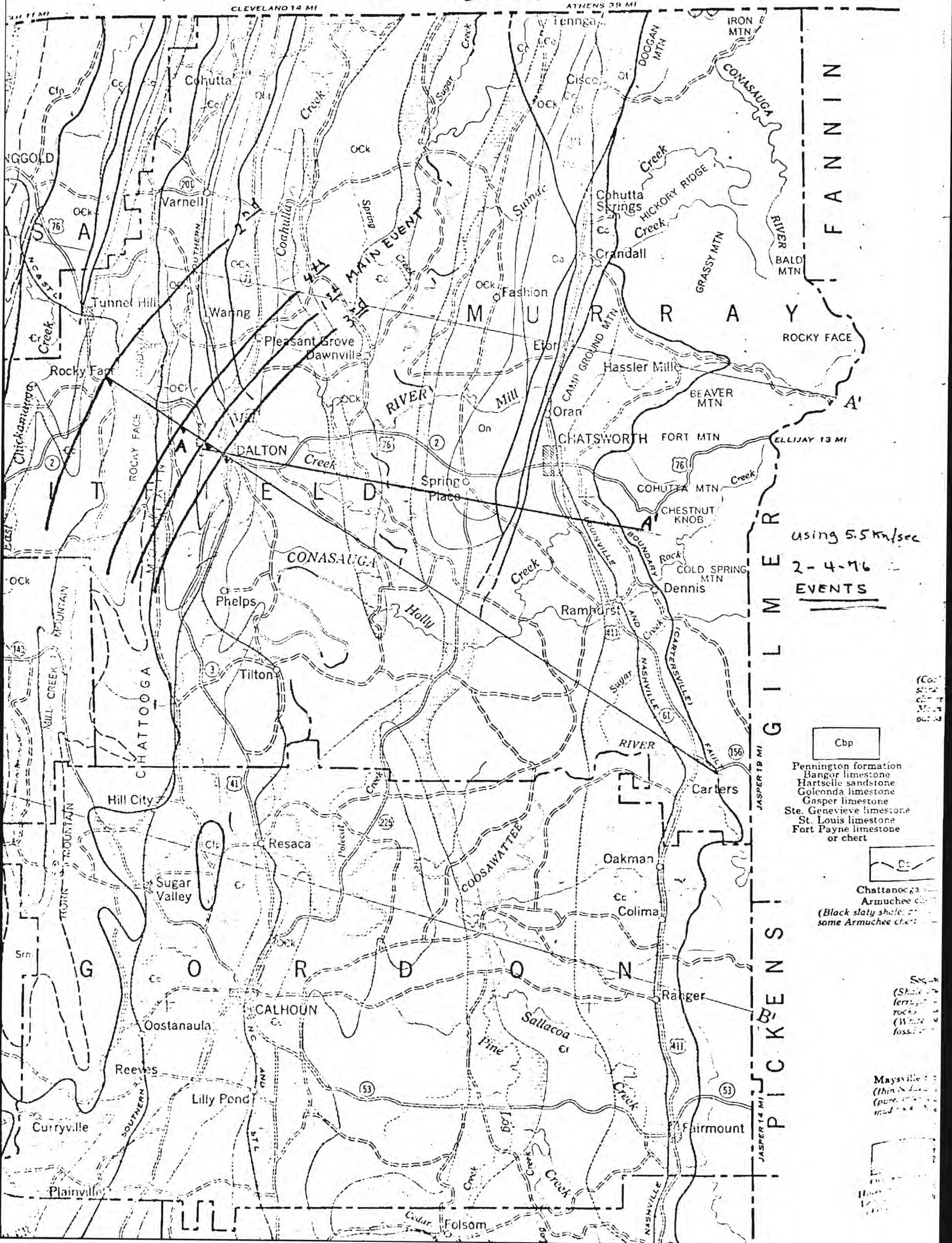
Dalton Earthquake Data Recorded

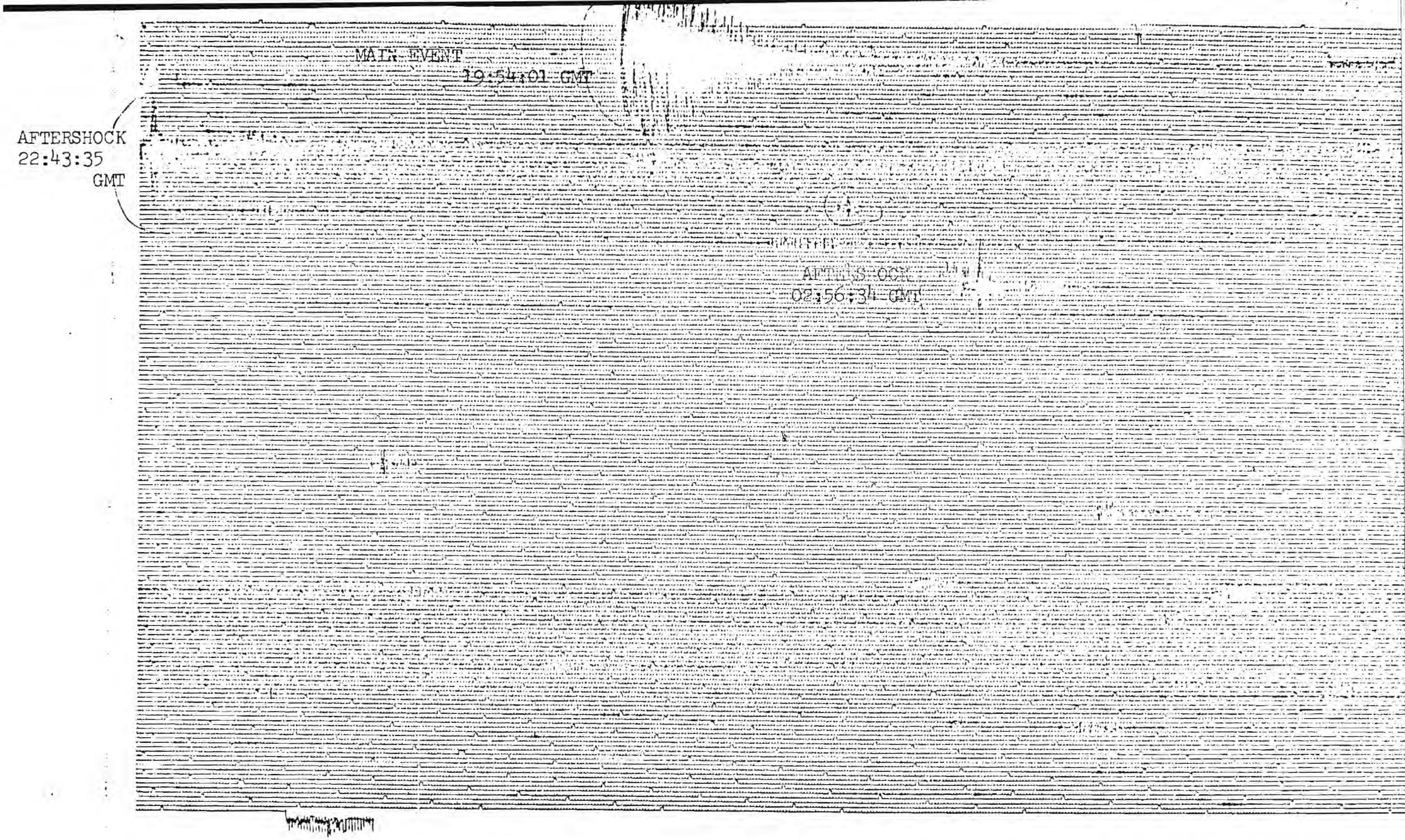
On The Carters Dam Seismograph

DATE	DAY	GMT	S-P (sec)	1^{st} Motion	$\frac{P}{S}$	P amp (in)	S amp (in)
10-29-75	Wednesday	21:13:09	5.1	?	.18	.02 in	.11 in
11-03-75	Monday	15:24:25	5.1	?	.48	.06 in	.14 in
11-19-75	Wednesday	22:03:36	4.0	?	.17	.02 in	.12 in
12-11-75	Thursday	18:43:50	4.0	?	.25	.01 in	.04 in
12-16-75	Tuesday	21:32:19	4.3	?	.64	.07 in	.11 in
12-30-75	Wednesday	19:41:21	4.1	?	.07	.10 in	.14 in
1-14-76	Wednesday	21:31:11	4.3	up	.22	.02 in	.09 in
1-19-76	Monday	17:38:45	4.1	up	.01	.01 in	.93 in
1-19-76	Monday	21:54:01	4.2	?	.22	.04 in	.18 in
1-23-76	Friday	18:57:15	4.3	?	.25	.02 in	.08 in
1-29-76	Tuesday	17:43:14	4.4	?	.20	.06 in	.29 in
2-3-76	Tuesday	17:11:01	4.2	up	.33	.05 in	.18 in
2-4-76	Wednesday	19:54:00	4.5	?		.70 in	saturated
2-4-76	Wednesday	20:42:31	5.5	?	.33	.03 in	.09 in
2-4-76	Wednesday	22:43:35	4.3	?	.16	.10 in	.64 in
2-4-76	Wednesday	02:54:36	4.7	up	.09	.05 in	.54 in
2-9-76	Monday	17:02:55	4.5	?		.03 in	?
2-12-76	Thursday	21:40:50	4.5	?	.25	.01 in	.04 in
2-21-76	Saturday	15:49:28.7	4.20	down			
2-25-76	Wednesday	23:22:34.8	4.5	up	.36	.04 in	.11 in
2-26-76	Thursday	17:01:54.1	4.8	down	.29	.03 in	.12 in

GEOLOGIC MAP OF NORTHWEST GEORGIA BUTTS 1946

Figure 2a





CARTERS DAM RECORD (CDG) OF FEBRUARY 4, 1976

MAIN EVENT AND AFTERSHOCKS SHOWN

(REDUCED SCALE)

FIGURE 3

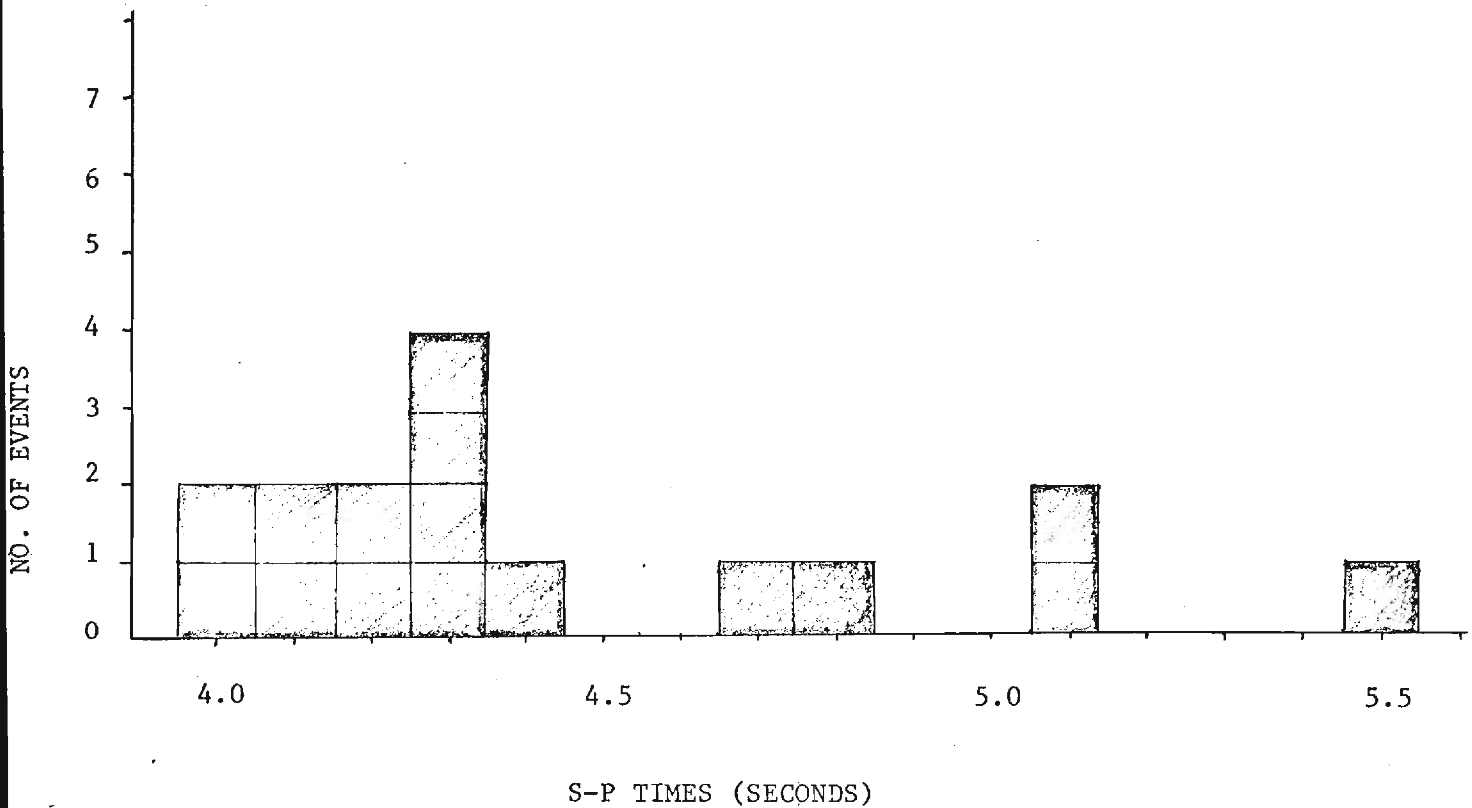


FIGURE 4

corded for 48 hours. The records showed no evidence of activity during this time.

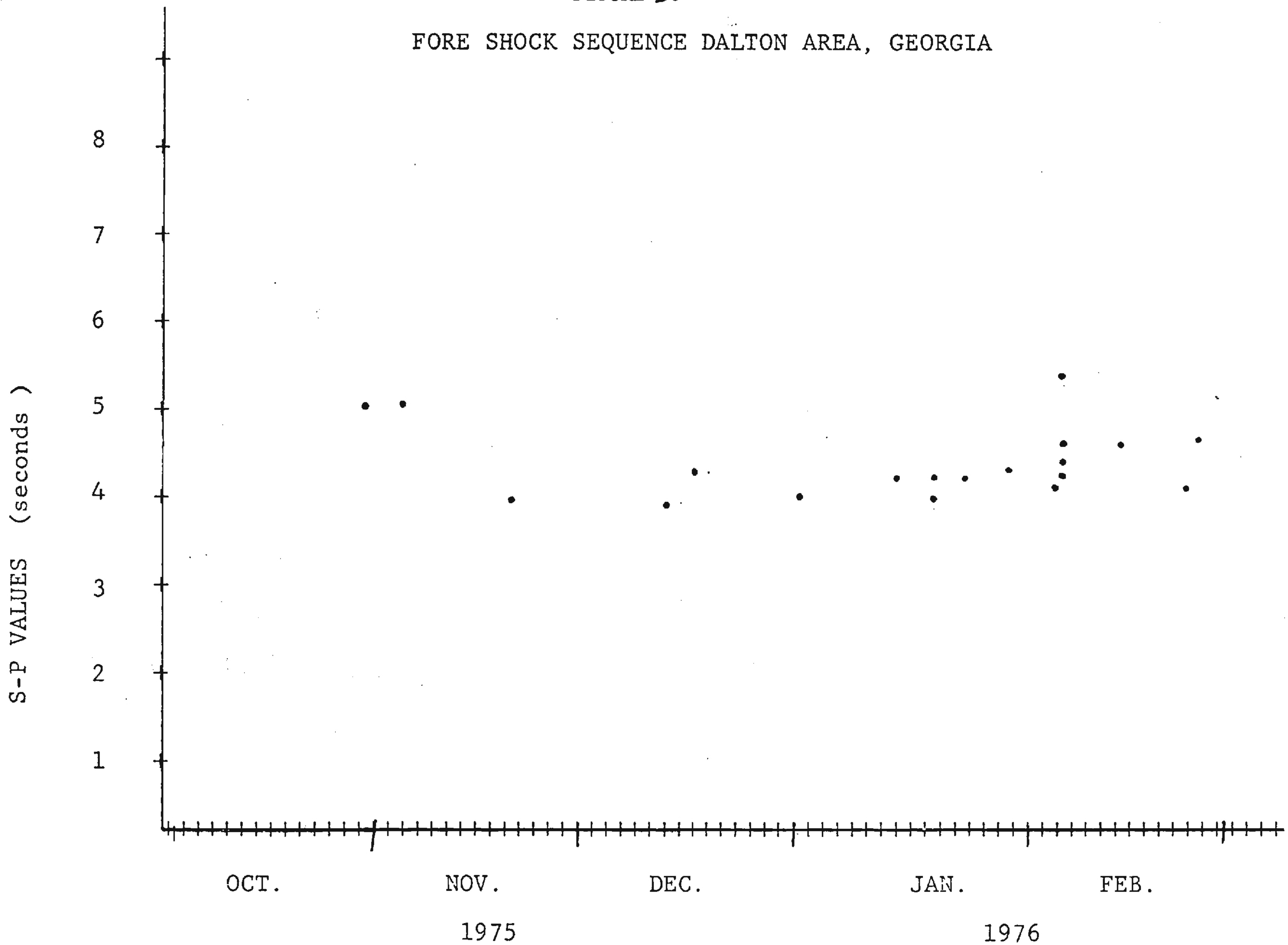
Trip No. 2 again involved taking the two smoked paper monitors out in the field. Since the first locations gave no data it was decided to relocate the instruments. The units were moved to a region near Cisco, Georgia. The units recorded for 68 hours. One event was recorded. The event occurred Thursday at 21:40:49 Universal Time. The S-P time as best determined was 4.0 seconds. It was noted that the P wave had a much greater amplitude than the S wave. The ratio of P amplitude to S amplitude was 2.83. This event was recorded only on smoked paper recorder #1 operating with a gain setting of 3.4 x 10. The other unit apparently was not operating properly at the time. The ground motion for this event was down.

The Carters Dam Station also recorded the same event at 21:40:50 Universal Time. The S-P as measured was 4.5 seconds. The P wave amplitude here was much smaller than the S wave amplitude with a P:S ratio of 0.25. Based on these two recordings it was determined that this event occurred somewhere near Dalton, Georgia, consistent with the main event of February 4, 1976.

With this small amount of data it was decided that the seismic activity was occurring in the Dalton area. The third trip involved taking two smoked paper units and 3 tape recording units and setting up four stations in the Dalton area. (see Table 3) The stations recorded for 48 hours. One event occurred on Saturday, at 15:49;25 GMT at Station #4 and also 15:49:25 GMT at Station #2. Since this event was recorded on a tape unit the event was played back on a strip chart and on smoked paper. The P-wave amplitude on the record at Station #2 is much greater than the S amplitude with a P:S ratio of 1.46. For Station #4, the reverse is true. The S wave amplitude

FIGURE 5.

FORE SHOCK SEQUENCE DALTON AREA, GEORGIA



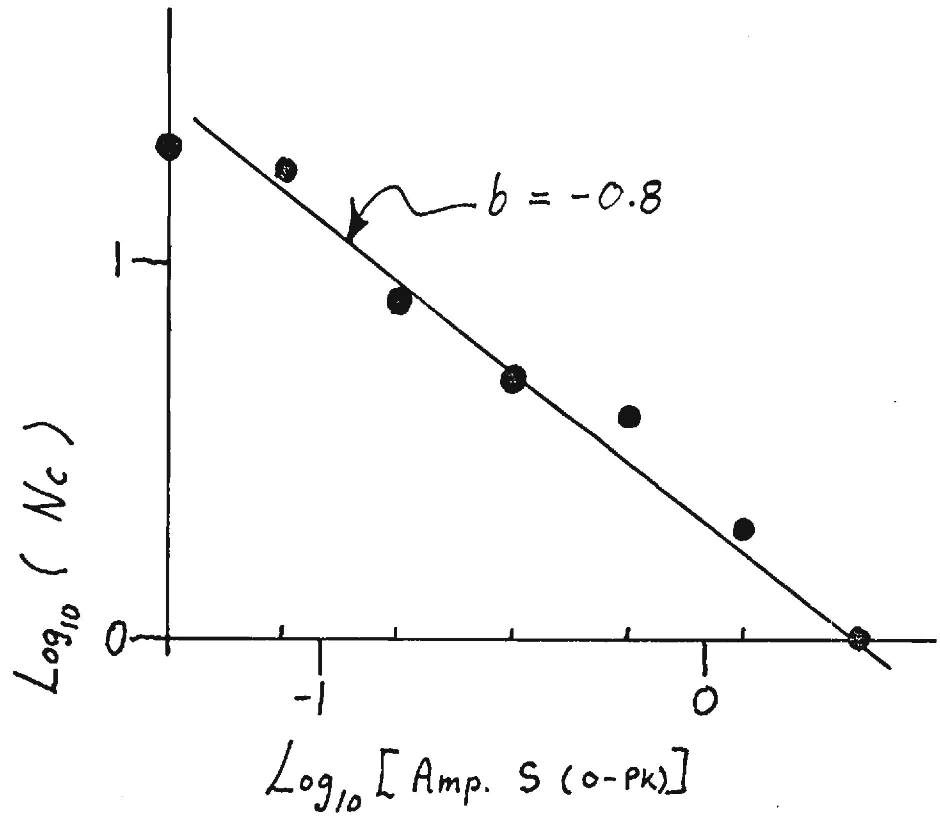


FIGURE VI.

TABLE 3

AFTERSHOCK MONITORING STATIONS

Trip number 1	February 10, 1976 through February 12, 1976 48 hours	
Station 1	85°02'55" W 34°46'26"N	
	Tunnel Hill, Ga., 7.5' Quad, South of Mt. Vernon Church	
Station 2	84°52'35"W 34°55'25"N	
	Cohutta, Ga.-Tenn 7.5' Quad, Near Cave Hollow, Varnel, Ga. area North of Hwy. 2	
Trip number 2	February 14, 1976 through February 15, 1976 48 hours	
Station 1	84°40'25"W 34°58'25"N	
	Cohutta Mt. Ga.-Tenn 15' Quad, Near Cisco, Ga.	
Station 2	84°42'45"W 34°56'59"N	
	Cohutta Mt. Ga.-Tenn 15'Quad, Near Cisco, Ga.	
Trip number 3	February 20, 1976 through February 22, 1976 48 hours	
Station 1	84°57'57"W 34°44'55"N	
	Dalton South 7.5' Quad, On hilltop near Radio Antenna	
Station 2	84°58'30"W 34°43'35"N	
	Dalton South 7.5' Quad, At end of road (see map)	
Station 3	84°55'43"W 34°43'37"N	
	Dalton South 7.5' Quad, Subdivision Loop (near sewage plant) (see map)	
Station 4	85°00'15"W 34°44'30"N	
	Villanow 7.5" Quad, Just west of I75 along dirt road heading northwest	

TABLE 3 continued

Trip number 4 March 3, 1976 through March 7, 1976 32 hours

Station 1	$84^{\circ}54'00''W$	$34^{\circ}47'10''N$
	Dalton North, 7.5' Quad, 1'st road to right heading west on Hwy. I75 past Coahulla Creek (road is dirt) Take 2'nd left off dirt road go 175' stop.	
Station 2	$84^{\circ}41'00''W$	$34^{\circ}46'29''W$
	Chatsworth, Ga. 7.5' Quad, 1'st dirt road to right past fork of highway 52-76, past fork, 1'st dirt road to right then 1'st right go 100' stop.	
Station 3	$84^{\circ}50'39''W$	$34^{\circ}43'34''N$
	Calhoun NE, 7.5 Quad,	
Station 4	$84^{\circ}53'34''W$	$34^{\circ}43'35''N$
	Dalton, Ga. 7.5' Quad, 2'nd road past Coahulla Creek heading East on highway 76, near garbage dump	

is greater than the P-wave amplitude with a P:S ratio of 0.85. From the strip chart records for both stations the appearance of a possible reflector was noted after the first P phase and before the first S phase. The S-P for Station #2 was 1.480 seconds and for Station #4, 2.216 seconds as determined from strip charts.

The direction of first motion for both stations could not be determined because the directions of motion on the instruments have not been calaborated as of this time.

The same event was recorded at CDG at 15:49:28.7 Universal Time. This shows a time difference of 3.7 seconds between Carters Dam Station and Station numbers 2 and 4. The P-wave amplitude was much smaller than the S-wave amplitude. The first motion (ground motion) from CDG was down, which was consistent with other recorded events. The S-P for CDG was 4.20 seconds.

Subsequent to trip #3 a smoked paper unit was left in the Dalton area at Station #3 as indicated in the location table for trip #3. This instrument recorded continuously for about two weeks. For this period of time one reliable event occurred on Wednesday February 25, 1975 at 23:22:35 Universal Time. This event gave an S-P of 2.1 seconds. The P-wave amplitude again appears greater than the S-wave amplitude.

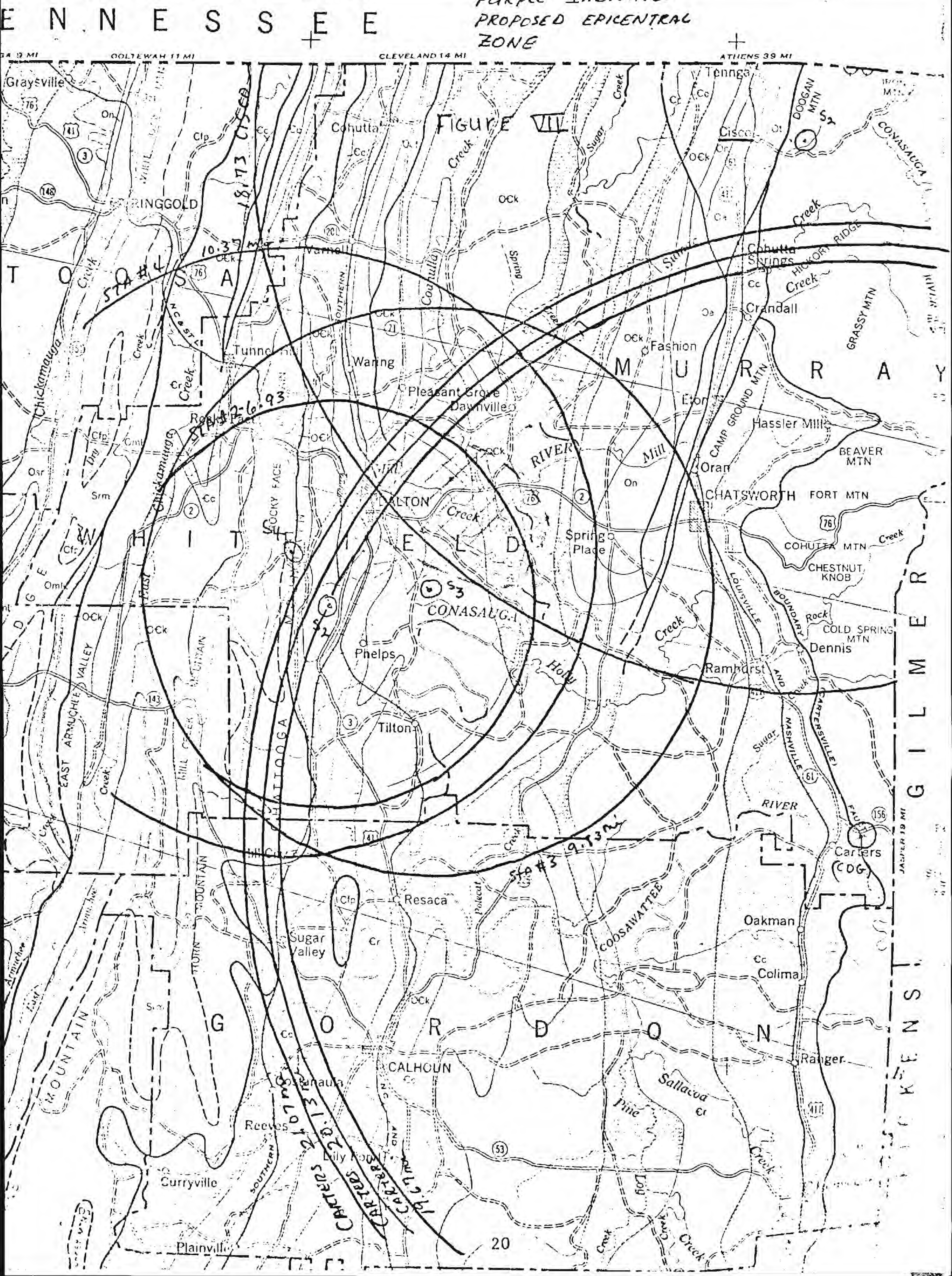
The same event was found on the Carters Dam Station record and occurred at 23:22:35.8 GMT with an S-P of 4.5 seconds. Again the P wave amplitude is small compared to the S wave amplitude giving a P:S ratio of 0.36. The first motion at CDG was up.

With the above data and using the relation, $1.37 \times (S-P)\ V_P = \text{Distance}$, for determining radial distance from each station a plausible epicentral zone was delineated. This zone is centered about $34^{o}45'$ N, $84^{o}52'$ W and has a width of about 6 km. Using a P wave velocity of 5.5 km/sec, the distances given in Table 4 are obtained. The station locations and radial distances are plotted on the geologic map of NW Georgia. From the radial distance plotted from each station the area outlined by diagonal lines appears to be the epicentral area.

TABLE 4

Station	(S-P)	distance
Cisco, Ga.	(4)	30.14 km
Carters Dam	(4.3)	32.40 km
Dalton	(2.216)	16.69 km
Sta. #4		
Dalton	(1.48)	11.15 km
Sta. #2		
Carters Dam	(4.2)	31.65 km
Dalton	(2.1)	15.82 km
Sta. #3		
Carters Dam	(4.5)	33.91 km

PURPLE INDICATES
PROPOSED EPICENTRAL
ZONE



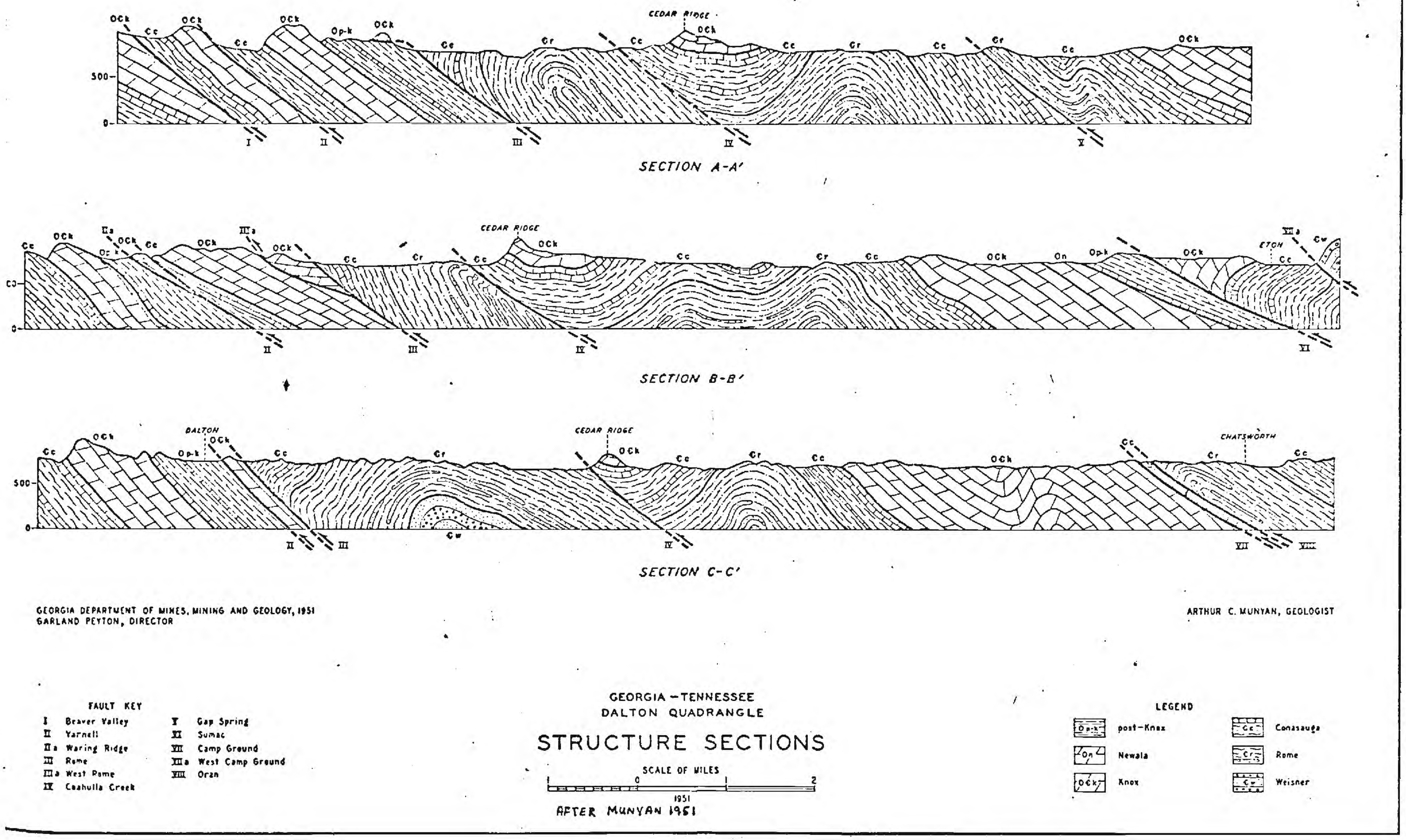

CEDAR RIDGE
SECTION A-A'
CEDAR RIDGE
ETON
SECTION B-B'
DALTON
CEDAR RIDGE
CHATSWORTH
SECTION C-C'
GEORGIA DEPARTMENT OF MINES, MINING AND GEOLOGY, 1951
GARLAND PEYTON, DIRECTOR
ARTHUR C. MUNYAN, GEOLOGIST
FAULT KEY
I Beaver Valley
II Yarnell
IIa Waring Ridge
III Rome
IIIa West Rome
IV Coahulla Creek
V Gap Spring
VI Sumac
VII Camp Ground
VIIa West Camp Ground
VIII Oran
GEORGIA - TENNESSEE
DALTON QUADRANGLE
STRUCTURE SECTIONS
SCALE OF MILES
1951
AFTER MUNYAN 1951
LEGEND
post-Knox
Newala
Knox
Conasauga
Rome
Weisner

FIGURE 8

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

June 9, 1976

Lt. Col. Donald R. Pope
Department of the Army
Mobile District, Corps of Engineers
P.O. Box 2288
Mobile, Alabama 36628

Subject: Quarterly Letter Report Number 9 covering period of March 1, 1976 to May 31, 1976

Reference: Contract No. DACW01-74-C-0077, Microearthquake Monitoring, Carters Dam, Georgia.

Dear Sirs:

The seismic station has been operating Monday through Saturday during normal work weeks. Occasional time was lost due to instrument malfunctions, related largely to the ink system. During the period of 1 March to 31 May 1976 the instrument was recording an average of 62% of the total available time. This corresponds to 64% for March, 63% for April, 58% for May. Of this recording time an insignificant 6% was obscured by noise. The maximum time coverage without weekend record changes would be about 70%.

The quarry explosion, tentatively identified to coincide with Whitestone Crushed Stone Operation, continue to be observed. The seismograms continued to show evidence of other industrial quarry activity at greater distances.

The aftershock sequence of the Dalton, Georgia earthquake of February 4, 1976 continued during the period. However, the activity has declined significantly and identification of aftershocks has been made more uncertain by quarry explosions near Dalton. The evaluation of this data is still in progress.

A study was started to determine a local magnitude scale for the Carters Dam instrument. This scale will allow estimation of the magnitude of local as well as regional events. This study has not yet been completed.

An event which could be either an explosion or microearthquake was detected on May 6, 1976 with an S-P of 0.7-1.1 sec. The preliminary magnitude estimate of the event gives $M = -1.45$. The distance was approximately 7.0 km. The resource manager knew of no blasting in the area of the dam by Carters Dam personel. However, state highway personnel questioned admitted that they may have blasted near Carters Dam on May 6, 1976 and we have observed evidence of blasting near the highway. We believe blasting explains this event.

Lt. Col. Donald R. Pope
2'nd page
June 9, 1976

A similar event occurred on December 18, 1975 and we believe blasting on the road may explain this event also. Illustrations of these events are enclosed for your examination.

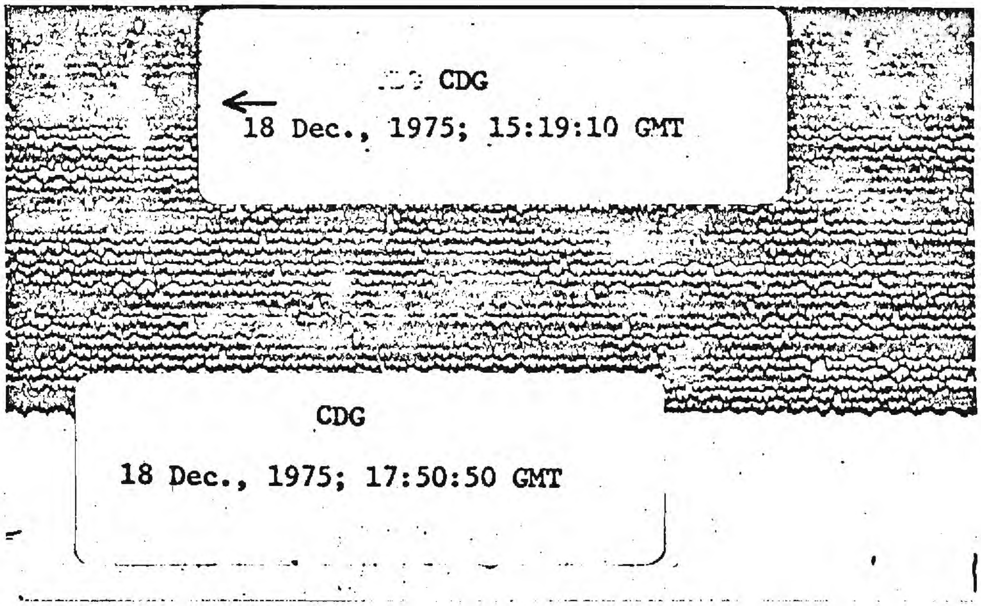
With the exception of the Dalton event and possible explosions noted above, no microearthquake activity has been detected in the vicinity of the dam. If any events occurred their amplitudes were below the detection level of the seismograph. Based on our preliminary magnitude estimate for the explosion the detection level is approximately a $M_L = -2.0$ within 5.0 km of the station.

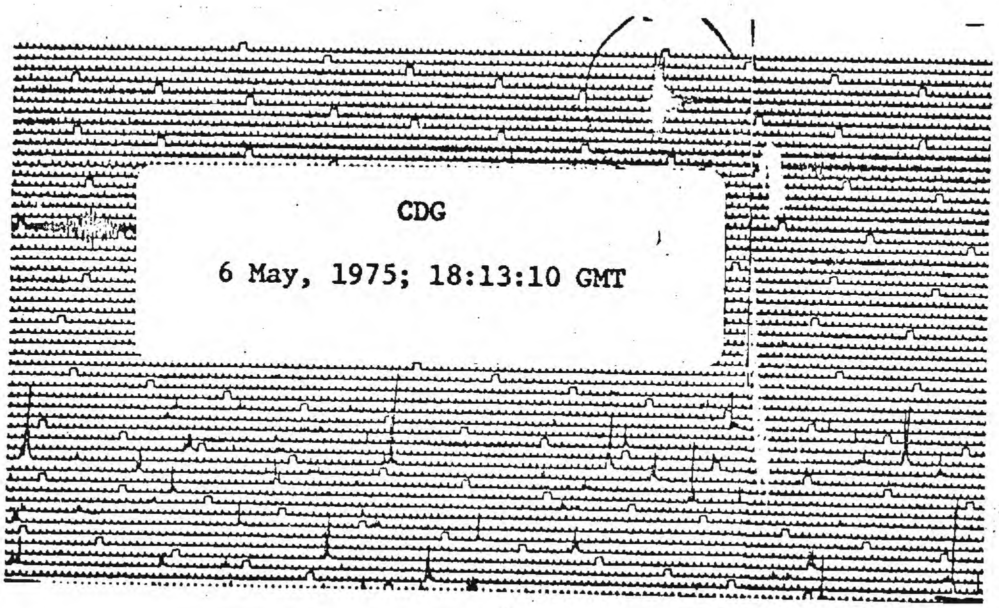
Respectfully submitted,

Leland Timothy Long
Associate Professor of Geophysics

LTL:jg

Enclosure


CDG
18 Dec., 1975; 15:19:10 GMT
CDG
18 Dec., 1975; 17:50:50 GMT


CDG
6 May, 1975; 18:13:10 GMT

G-35-612

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

September 20, 1976

Lt. Col. Donald R. Pope
Department of the Army
Mobile District, Corps of Engineers
P.O. Box 2288
Mobile, AL 36628

Subject: Quarterly Letter Report Number 10, covering period of June 1, 1976 to August 31, 1976

Reference: Contract NO. DACW01-74-C-0077, Microearthquake Monitoring, Carters Dam, Georgia

Dear Sirs:

The seismic station has been operating Monday through Saturday during normal work weeks. Occasional time was lost due to instrument malfunctions, related largely to the ink system. During the period of 1 June to 31 August, 1976 the instrument was recording an average of 46% of the total available time. This corresponds to 43% for June, 41% for July, and 60% for August. Of this recording time an insignificant 3% was obscured by noise. The maximum time coverage without weekend record changes would be about 70%.

An outline explaining the operation of the seismic equipment was written and a copy of the report is enclosed.

A signature of a possible earthquake, near Tellico Plains, Tennessee, was detected. The size of the event was small ($M_L \cong 1.5$) and quarry explosions cannot be ruled out.

No microearthquake activity has been detected in the vicinity of the dam. If any events occurred, their amplitudes were below the detection level of the seismograph.

Respectively submitted.

Leland Timothy Long
Associate Professor

LTL/cma

THE CARTERS DAM SEISMIC OBSERVATORY

Introduction

The Carters Dam seismic station or CDG as designated by the USGS, was established by the School of Geophysical Sciences at Georgia Tech on the request of the U.S. Army Corps of Engineers. One objective of the seismic station is to monitor the vicinity of the reservoir for earthquakes. The station will provide nearly continuous data from approximately one year prior to the initiation of filling of the reservoir until beyond one year after the reservoir was completely filled. To date, August 1976, no significant events have been detected in the immediate vicinity of the reservoir. However, numerous regional earthquakes and industrial explosions such as those detonated in quarries to mine the rock have been recorded by the Carters Dam seismograph. The object of this report is to describe significant events previously recorded on the Carters Dam seismograph and hence provide a guide for the identification of events which are recorded by the Carters Dam seismograph. Seismograms of earthquakes can be complex and therefore, only a cursory explanation is offered here. For a more complete treatment of seismogram interpretations one should consult texts such as _Earthquake Interpretations_ by Ruth Simon, 1968 or _Principles Underlying the Interpretation of Seismograms_, U.S. Dept. of Commerce, Spec. Pub. 254, 1966.

Basic Seismic Waves

An earthquake is the ground movement resulting from a sudden displacement of rock along a plane surface. Plane surfaces in the earth which show displacement of one side relative to the other are called faults. The area of a plane surface involved with movement for a single detectable earthquake can range from a few meters to hundreds of kilometers. The amplitude of the ground motion for an earthquake will be roughly proportional to the size of the fault surface. Earthquakes which are too small to be felt, can be detected from faults involving movement of only a few square meters of area. These small events are often called microearthquakes. Large earthquakes involve movements along 10 to 100 km of a fault. These large events can be felt for distances of 1000 km radius and are detected by seismographs worldwide.

When a rock fractures, causing an earthquake, energy is carried away from the zone of displacement in the form of seismic waves. Three types of waves are commonly observed at distance. These are the primary or P-waves, secondary or S-waves, and the Rayleigh and Love surface waves. A P-wave is a volume change or compression that can be transmitted through a solid or liquid. The P-wave is also termed a longitudinal wave since the motion of a particle in the solid is along the direction of propagation. The S-wave has a particle motion that is at right angles to the direction of propagation and represents the propagation of a shear or rotation of the material. S-waves can only be transmitted through a solid.

Surface waves can be either Rayleigh waves or Love waves. The particle motion of a Rayleigh wave is elliptical retrograde in a vertical plane. A particle will travel vertically when looking at it from the direction of propagation and from the side the particle will travel in an ellipse with a ratio of 3:2 for the vertical and horizontal axis. When at the top of the ellipse, the particle will appear to move in the direction opposite to the direction of propagation. A Love wave can propagate only where a near-surface, low-velocity layer exists. The Love wave is a horizontally polarized S-wave.

The motion of a particle is horizontal and perpendicular to the direction of propagation. Since the geophone at Carters Dam only records the verticle component of the ground motion, Love waves are not observed on the CDG seismograms.

The velocity of each wave depends on the elastic properties and density of the rocks of the earth's crust. The P-wave velocity is the fastest at 5.0 to 8.3 km/sec for most crustal seismic wave arrivals. The S-wave velocities range from about 3.0 to 4.5 km/sec. The surface waves propagate slower than the S-wave in the same material. However, their velocity depends on their frequency of vibration. For a typical surface wave observed on seismograms, the lowest frequencies propagate at the fastest velocities. On the CDG records, surface waves consist of a series of oscillations with increasing frequency following the arrival of the S-wave. Surface waves will not appear on all records since their amplitudes are attenuated by topographic relief and the event's location must be close to the earth's surface for these waves to be generated efficiently.

The Seismometer

A seismograph is an instrument used to record earthquakes and other ground movement. It is composed of a geophone, an amplifier and an recording device. The geophone is a "listening device" that detects small ground motions and converts the motion to an electrical signal. The amplitude of the electrical signal depends on the frequency of ground motion driving the geophone. The frequency dependence of the geophone response is determined by mechanical parameters such as the mass of the moving coil, and a damping factor. The spring constant and mass determine its free period or resonance frequency. Damping has the effect of reducing the response at the resonant frequency and most seismometer geophones are critically damped. At CDG the geophone is critically damped and has a 1.0 Hz free period.

For typical background seismic noise, the voltage generated is on the order of 10 to 100 microvolts. Consequently the voltage must be amplified to be recorded. Also, the voltage is often conditioned to remove signals at frequencies which might interfere with the seismic data. The amplifiers at Carters Dam are designed to cause a maximum displacement response at 10 to 15 Hertz. If the response of the geophone, amplifier, and recorder are known, then the recorded trace on the seismogram can be corrected to give the actual particle velocity or displacement of the ground. At Carters Dam the recording device is a helical drum recorder using a capillary ink pen to write the trace.

Record Interpretation

Reading records correctly takes practice. The following is a discussion of how to read the most important parameters of an earthquake from the CDG seismograms. For an earthquake, two readings are most useful. One is the S-P time and the other is the time that the P-wave arrives at the station. To find the P-wave arrival time, note the time that the record was started and find the first hour mark. For example, if the record was mounted at 13:07 GMT, then note the hour mark for 14:00 GMT. Then count from this time by hour marks which are separated by about 3 lines to the hour mark just before the event occurred. Then count the minute marks and then the second marks up to the event. Add to the number of seconds the fraction of a second remaining between the last second mark and the event. In counting, the next hour after 2300 is 0000 hours and this begins the next day. The time of the first arrival should give the P-wave arrival time. The hour and minute marks can be recognized by their length. The hour marks are two seconds in duration while the minute marks are one second long. The S-P time is found by counting or measuring the number of seconds between the P-wave arrival time and the S-wave arrival time. If these two times are known, then other records from other stations can be checked and the location of the event found by comparing the arrival times.

The P-wave is the first wave to arrive. It is followed by the S-wave. The more distant the event the longer the S-P time. Picking the S-wave is more difficult because parts of the P-wave, arriving just before the S-wave arrival can interfere. Usually, the S-wave arrival is the first sustained jump in the amplitude of the trace. However, the amplitude of each of the P and S waves depends on the orientation of the fault with respect to the station and the propagation path. Hence, some of the waves may not be large enough to be seen on a record.

The following series of figures were obtained from actual Carters Dam records. On each, the P-waves and S-waves of typical events are marked. Also marked are comments on other signatures that are detected such as minute marks and teleseisms (i.e., large earthquakes at distances greater that 1000 km).

A portion of the seismogram from February 4, 1976 (Figure 1) shows a local earthquake and one of three aftershocks that occurred north of CDG on the Georgia-Tennessee border. The maximum S-wave amplitude cannot be measured for the main event because the pen rotation was limited by the instrumentation. Because of this limitation, the maximum amplitude is unknown and should be noted as saturated so that a lower limit on the amplitude can be established.

Saturation is evident from the coincidence of the peak pen movements that occurred after the arrival of the S-wave, as compared to the random amplitude of the following waves. The record of 4 February also shows a teleseism. This teleseism occurred at a distance of 6000 km on the border of Chile and Bolivia and had a magnitude of 5.8. Typically, only the P-waves of teleseisms are recorded on short-period stations like CDG.

Figure 2a of August 28, 1975 shows a magnitude 4.4 earthquake that occurred near Birmingham, Alabama. Figure 2b shows a natural event which occurred near Lake Jocassee, South Carolina. The Jocassee event had a magnitude 3.4 and caused no damage. The event recorded on September 3, 1975, (Figure 2c) was most probably a quarry blast. The signature shows clearly the variation of frequency with respect to time of the low-frequency surface waves.

Figure 2d is a magnitude 6.0 earthquake that occurred near Sumatra about 17,000 km from CDG. The February 3, 1976 record (Figure 2e) shows a large earthquake that occurred in Guatamala with a magnitude of 7.9 at a distance of 2200 km. The waves generated by an earthquake differ not only in their particle motions and velocities but also in their characteristic frequencies observed on seismograms. Generally, the frequency of a P-wave is the highest followed next by S-waves and then surface waves. However, the frequencies observed at a station depend upon the distance and size of the event and also the instrument response. The crust of the earth will propagate a wave of lower frequency better than one of higher frequency. Therefore, as the distance increases, the high frequencies will be attenuated and not observed on the seismogram. The size of the event also affects the frequencies generated because the fault size is larger. The size of the event depends on the fault size and on the stress causing the earthquake and hence also on the type of rock in which the earthquake occurrs. A larger fault will typically produce more energy in the lower frequencies. The instrument response affects the recorded frequencies by attenuating those frequencies above and below the peak response. Hence, the recorded frequencies will be close to this peak frequency, though they will still vary with the frequency as shown by the Guatamala event (Figure 2e). The surface waves are the longest period waves with periods around 4-10 seconds. They can be seen clearly below the P and S- waves. Figure 2f shows a low frequency (2-6 seconds) motion observed when a weather front crosses the Carters Dam area. This may be related to wind motion coupled to the ground by trees or wave action. The event shown in Figure 2f is probably a large quarry explosion. It shows multiple arrivals in the P-wave which indicate different propagation peaks for the P-waves in the crust.

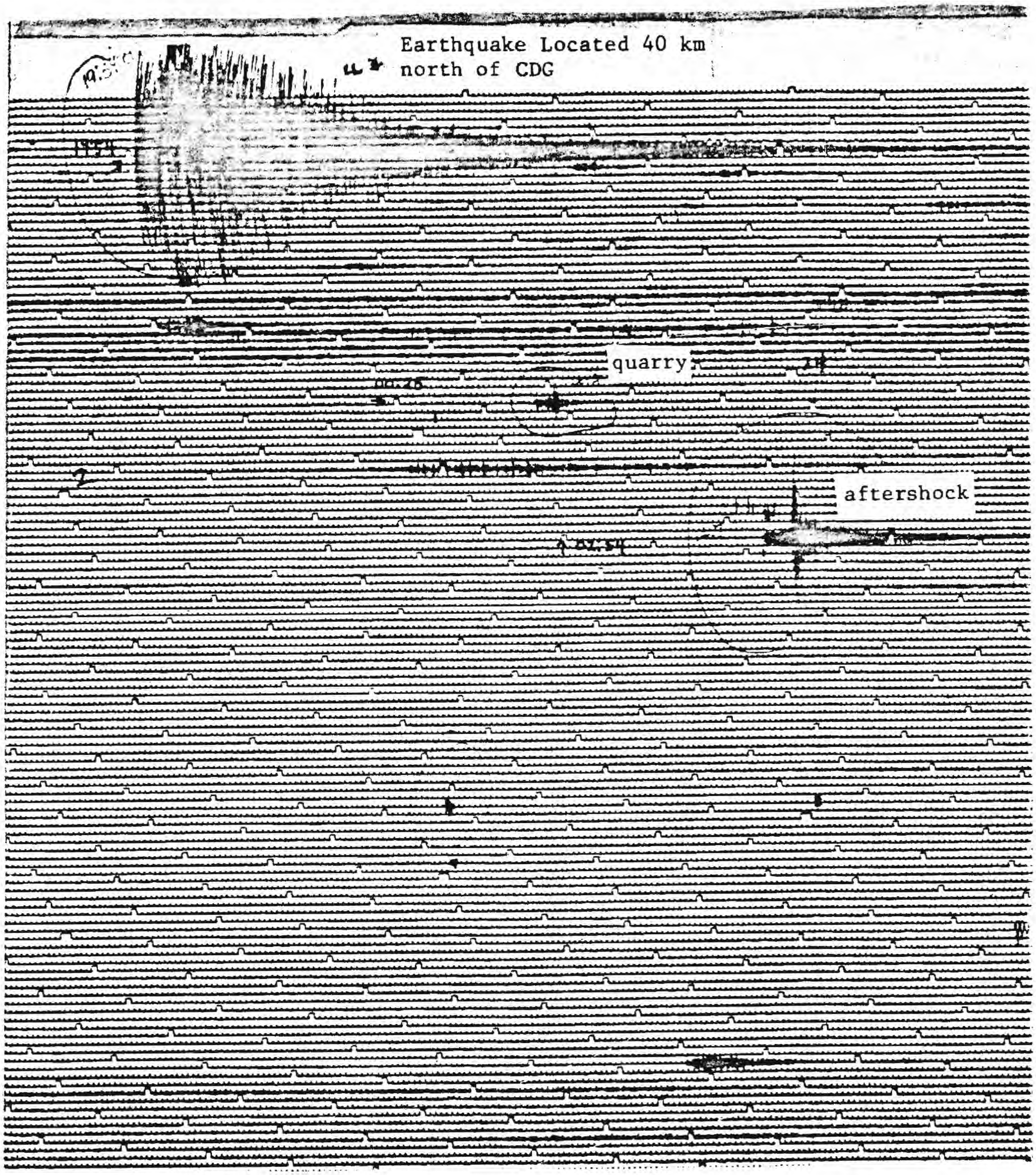
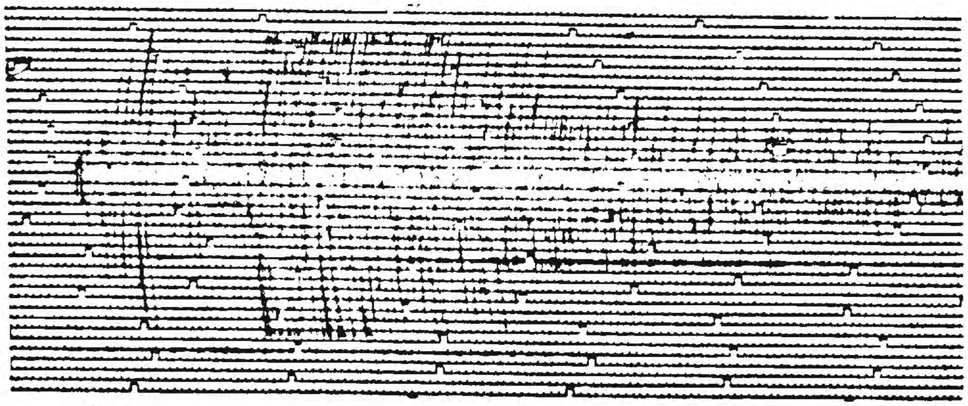


Figure 1. Portion of Seismogram for February 4, 1976.

(a)



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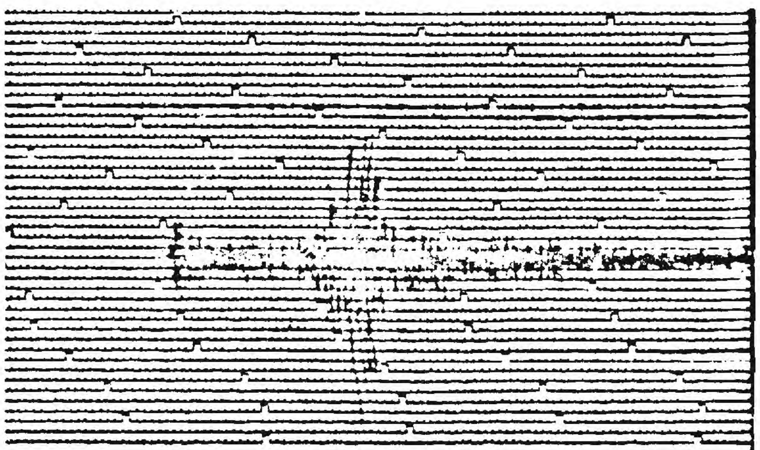


(c)

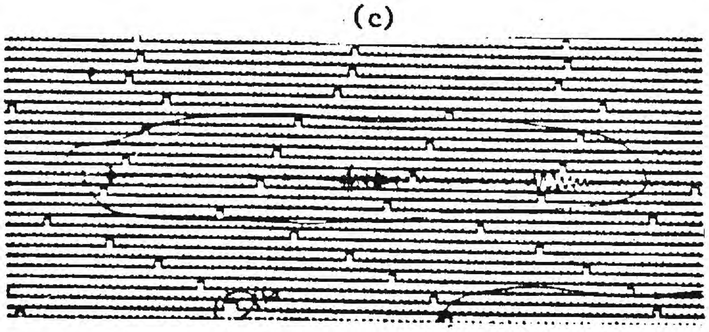
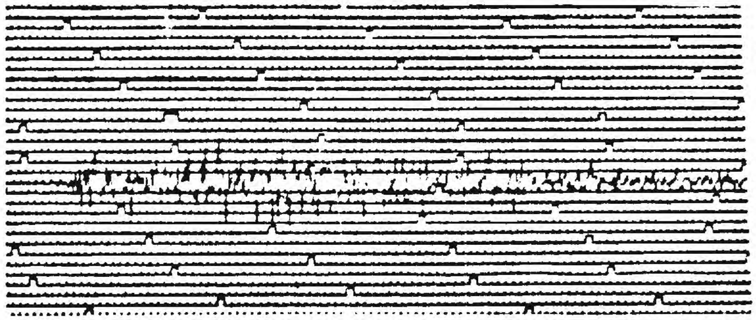
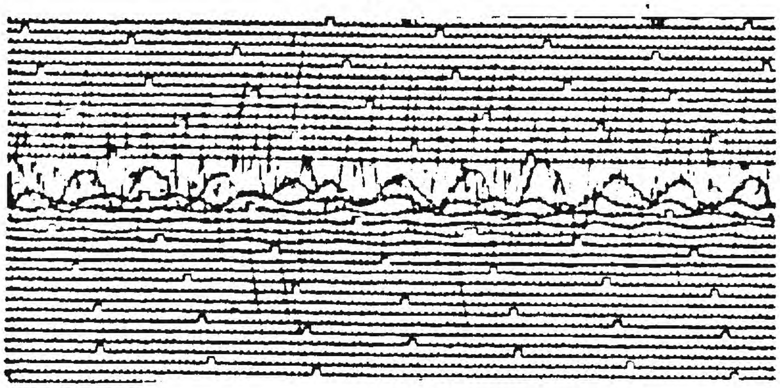


Figure 2 a,b,c. Sample events recorded at CDG.

(d)



(e)



(f)

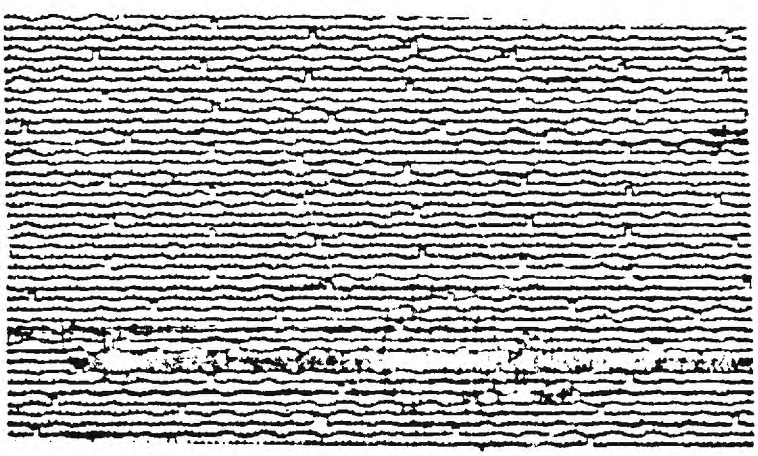


Figure 2 d,e,f. Sample events recorded at CDG.

G-35-612

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

January 14, 1977

Lt. Col. Donald R. Pope
Department of the Army
Mobile District, Corps of Engineers
P.O. Box 2288
Mobile, AL 36628

Subject: Final Report, covering period of 3 June 1974 to 31 December 1976.

Reference: Contract No. DACW01-C-0077, Microearthquake Monitoring, Carters Dam, Georgia.

Dear Sirs:

The CDG seismic station has been in operation Monday through Saturday, during normal work weeks. During the period of 1 September to 31 December, 1976, the instrument was recording an average of 55% of the total available time. This corresponds to 50% for September, 62% for October, 73% for November, and 30% for December. Of the total recording time available no noise was detected. A plot showing the water level and the percent of coverage since the seismograph was installed is attached.

The six major regional events recorded at CDG are given below.

Date	Time	Lat	Long	Loc	Mag
Apr 3, 1974	23:05:02.5	38.59	88.09	South Illinois	4.5
May 30, 1974	21:28:37.2	37.38	80.42	Virginia	not available
Nov 22, 1974	5:25:55.5	32.90	80.15	South Carolina	4.7
Aug 29, 1975	4:22:51.9	33.82	86.60	Birmingham, AL	4.4
Nov 25, 1975	15:17:33.70	34.87	82.96	Lake Jocassee, SC	3.2
Feb 4, 1975	19:53:55.0	34.75	84.87	Conasauga, TN	3.1

Copies and analyses of these records have been given in the quarterly letter reports.

During the term of the project, a number of separate reportswere prepared. These include:

1. General Description of Seismic Monitoring at Carters Dam, Georgia.
2. The Carters Dam Seismic Observatory
3. Calibration of the Seismic Observatory
4. Recommendations for Seismic Monitoring of Seismic Activity Assoicated with Reservoirs
5. A Local Magnitude Scale for Carters Dam

Copies of these reports are attached to this letter.

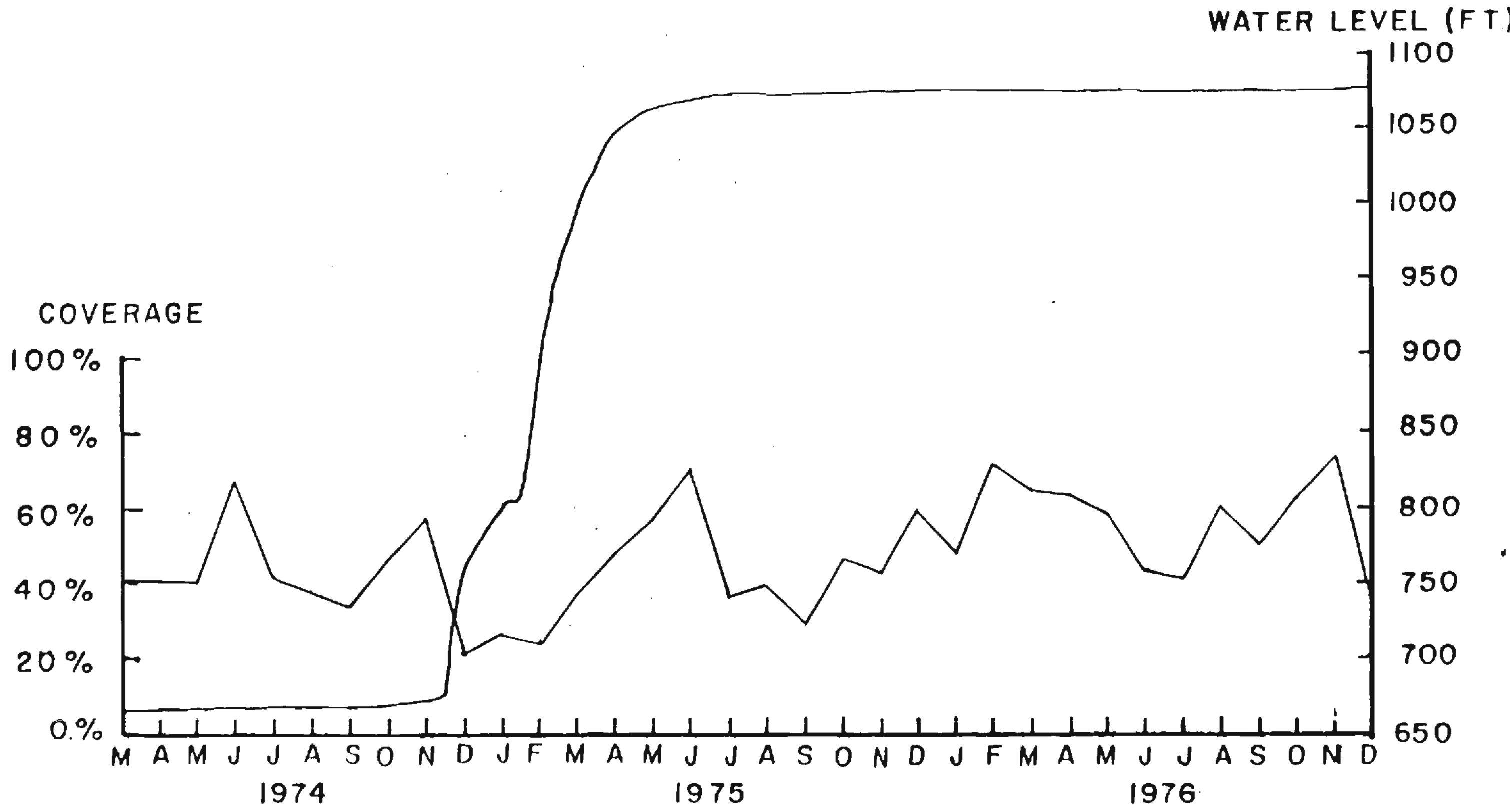
During the total term of this project (3 June 1974 to 31 December 1976) no microearthquake activity was detected within a 10 km radius of the dam. The closest natural event detected occurred at Conasauga, Tennèssee, a distance of 40 km from Carters Dam. If any events did occur, they either occurred when the instrument was not recording or their amplitudes were below the detection level of the seismograph. From the magnitude study (see attached reports) the minimum event that could be detected at a distance of 10 km would be about a magnitude of -0.5.

Respectfully submitted,

Leland Timothy Long
Associate Professor

LTL:cma

attachments



WATER LEVEL (FT)
1100
1050
1000
950
900
850
800
750
700
650
COVERAGE
100%
80%
60%
40%
20%
0.%
M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1974
1975
1976

Reference: "Microearthquake Monitoring, Carters Dam, Georgia" Contract No. DACW01-74-C-0077, U.S. Army, Corps of Engineers, Mobile District.

Title: General Description of Seismic Monitoring at Carters Dam, Ga.

Author: Dr. Leland Timothy Long

Date: 10 February 1974 (Revised 5 March 1976)

Purpose. Earthquake activity occurring in the vicinity of reservoirs usually consists of a foreshock sequence with an increasing rate of activity, a main event or sequence of main events, and an aftershock sequence. The duration of a total sequence which involves a significant magnitude 4.0 or larger event is typically in excess of a few months. Consequently, prediction of the main event of the sequence may be possible if instrumentation capable of recording the smaller foreshocks can be installed early in the sequence. The purpose of seismic monitoring at Carters Dam is to detect and identify local microearthquakes (if any) and to determine if there is any association between filling of the reservoir and the occurrence of the microearthquakes near Carters Dam.

Instrumentation. The recorder is located in the visitor's center above Carters Dam. The recorder is a helical drum recorder utalizing an ink writing system. The recording speed is 60 mm/min and the translation rate allows one day of recording for each record. The amplifier is a 6 db per step grain dc amplifier with a high-frequency (6db/octave) cut off now set at a 3 db point at 10 Hz. The system is capable of a flat response up to 80 Hz but local noise above 30 Hz seriously decreases the sensitivity of the system when used without the low-pass filter. The system was designed and assembled at Georgia Tech.

The system is powered by an 110V ac to dc ($\pm$ 12V) regulated power supply and contains internal batteries capable of maintaining operation during temporary power outages. Time control is provided by a Sprengnether temperature-compensated crystal timing system housed in a seperate container. A WWV receiver is in the unit for correcting the time to Universal time. The seismometer is located approximately 500 ft northwest of the recorder to isolate it from noise sources. The seismomemter is a 1.0 Hz Geospace instrument with a 500 KΩ coil. A low-power battery operated pre-amplifier was built into the seismometer by Georgia Tech to increase the signal level, reduce the line impedence and suppress extranious noise. The seismometer is housed in a weather-tight container mounted on a cememt pad. The cement pad is dug into the ground approximately two feet.

Record keeping and interpretation. At Carters Dam the recording paper is changed Monday through Friday by Corps of Engineer personnel to provide 5 days of recording time each week. Ideally, the records should be changed 7 days a week. The seismograms are mailed weekly to Georgia Tech. When received, the seismograms are examined for evidence of local (i.e less than 15 km) seismic activity. Other events which occur at distances greater than 15 km are catalogued for reference and identification. All unusual events are examined and catalogued. Once every three months, a short letter report is prepared to show the recording time and activity levels during the period. If local activity is identified a report will be submitted as soon as possible.

THE CARTERS DAM SEISMIC OBSERVATORY

Introduction

The Carters Dam seismic station or CDG as designated by the USGS, was established by the School of Geophysical Sciences at Georgia Tech on the request of the U.S. Army Corps of Engineers. One objective of the seismic station is to monitor the vicinity of the reservoir for earthquakes. The station will provide nearly continuous data from approximately one year prior to the initiation of filling of the reservoir until beyond one year after the reservoir was completely filled. To date, August 1976, no significant events have been detected in the immediate vicinity of the reservoir. However, numerous regional earthquakes and industrial explosions such as those detonated in quarries to mine the rock have been recorded by the Carters Dam seismograph. The object of this report is to describe significant events previously recorded on the Carters Dam seismograph and hence provide a guide for the identification of events which are recorded by the Carters Dam seismograph. Seismograms of earthquakes can be complex and therefore, only a cursory explanation is offered here. For a more complete treatment of seismogram interpretations one should consult texts such as Earthquake Interpretations by Ruth Simon, 1968 or Principles Underlying the Interpretation of Seismograms, U.S. Dept. of Commerce, Spec. Pub. 254, 1966.

Basic Seismic Waves

An earthquake is the ground movement resulting from a sudden displacement of rock along a plane surface. Plane surfaces in the earth which show displacement of one side relative to the other are called faults. The area of a plane surface involved with movement for a single detectable earthquake can range from a few meters to hundreds of kilometers. The amplitude of the ground motion for an earthquake will be roughly proportional to the size of the fault surface. Earthquakes which are too small to be felt, can be detected from faults involving movement of only a few square meters of area. These small events are often called microearthquakes. Large earthquakes involve movements along 10 to 100 km of a fault. These large events can be felt for distances of 1000 km radius and are detected by seismographs worldwide.

When a rock fractures, causing an earthquake, energy is carried away from the zone of displacement in the form of seismic waves. Three types of waves are commonly observed at distance. These are the primary or P-waves, secondary or S-waves, and the Rayleigh and Love surface waves. A P-wave is a volume change or compression that can be transmitted through a solid or liquid. The P-wave is also termed a longitudinal wave since the motion of a particle in the solid is along the direction of propagation. The S-wave has a particle motion that is at right angles to the direction of propagation and represents the propagation of a shear or rotation of the material. S-waves can only be transmitted through a solid.

Surface waves can be either Rayleigh waves or Love waves. The particle motion of a Rayleigh wave is elliptical retrograde in a vertical plane. A particle will travel vertically when looking at it from the direction of propagation and from the side the particle will travel in an ellipse with a ratio of 3:2 for the vertical and horizontal axis. When at the top of the ellipse, the particle will appear to move in the direction opposite to the direction of propagation. A Love wave can propagate only where a near-surface, low-velocity layer exists. The Love wave is a horizontally polarized S-wave.

The motion of a particle is horizontal and perpendicular to the direction of propagation. Since the geophone at Carters Dam only records the verticle component of the ground motion, Love waves are not observed on the CDG seismograms.

The velocity of each wave depends on the elastic properties and density of the rocks of the earth's crust. The P-wave velocity is the fastest at 5.0 to 8.3 km/sec for most crustal seismic wave arrivals. The S-wave velocities range from about 3.0 to 4.5 km/sec. The surface waves propagate slower than the S-wave in the same material. However, their velocity depends on their frequency of vibration. For a typical surface wave observed on seismograms, the lowest frequencies propagate at the fastest velocities. On the CDG records, surface waves consist of a series of oscillations with increasing frequency following the arrival of the S-wave. Surface waves will not appear on all records since their amplitudes are attenuated by topographic relief and the event's location must be close to the earth's surface for these waves to be generated efficiently.

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A seismograph is an instrument used to record earthquakes and other ground movement. It is composed of a geophone, an amplifier and an recording device. The geophone is a "listening device" that detects small ground motions and converts the motion to an electrical signal. The amplitude of the electrical signal depends on the frequency of ground motion driving the geophone. The frequency dependence of the geophone response is determined by mechanical parameters such as the mass of the moving coil, and a damping factor. The spring constant and mass determine its free period or resonance frequency. Damping has the effect of reducing the response at the resonant frequency and most seismometer geophones are critically damped. At CDG the geophone is critically damped and has a 1.0 Hz free period.

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Reading records correctly takes practice. The following is a discussion of how to read the most important parameters of an earthquake from the CDG seismograms. For an earthquake, two readings are most useful. One is the S-P time and the other is the time that the P-wave arrives at the station. To find the P-wave arrival time, note the time that the record was started and find the first hour mark. For example, if the record was mounted at 13:07 GMT, then note the hour mark for 14:00 GMT. Then count from this time by hour marks which are separated by about 3 lines to the hour mark just before the event occurred. Then count the minute marks and then the second marks up to the event. Add to the number of seconds the fraction of a second remaining between the last second mark and the event. In counting, the next hour after 2300 is 0000 hours and this begins the next day. The time of the first arrival should give the P-wave arrival time. The hour and minute marks can be recognized by their length. The hour marks are two seconds in duration while the minute marks are one second long. The S-P time is found by counting or measuring the number of seconds between the P-wave arrival time and the S-wave arrival time. If these two times are known, then other records from other stations can be checked and the location of the event found by comparing the arrival times.

The P-wave is the first wave to arrive. It is followed by the S-wave. The more distant the event the longer the S-P time. Picking the S-wave is more difficult because parts of the P-wave, arriving just before the S-wave arrival can interfere. Usually, the S-wave arrival is the first sustained jump in the amplitude of the trace. However, the amplitude of each of the P and S waves depends on the orientation of the fault with respect to the station and the propagation path. Hence, some of the waves may not be large enough to be seen on a record.

The following series of figures were obtained from actual Carters Dam records. On each, the P-waves and S-waves of typical events are marked. Also marked are comments on other signatures that are detected such as minute marks and teleseisms (i.e., large earthquakes at distances greater that 1000 km).

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Figure 2a of August 28, 1975 shows a magnitude 4.4 earthquake that occurred near Birmingham, Alabama. Figure 2b shows a natural event which occurred near Lake Jocassee, South Carolina. The Jocassee event had a magnitude 3.4 and caused no damage. The event recorded on September 3, 1975, (Figure 2c) was most probably a quarry blast. The signature shows clearly the variation of frequency with respect to time of the low-frequency surface waves.

Figure 2d is a magnitude 6.0 earthquake that occurred near Sumatra about 17,000 km from CDG. The February 3, 1976 record (Figure 2e) shows a large earthquake that occurred in Guatamala with a magnitude of 7.9 at a distance of 2200 km. The waves generated by an earthquake differ not only in their particle motions and velocities but also in their characteristic frequencies observed on seismograms. Generally, the frequency of a P-wave is the highest followed next by S-waves and then surface waves. However, the frequencies observed at a station depend upon the distance and size of the event and also the instrument response. The crust of the earth will propagate a wave of lower frequency better than one of higher frequency. Therefore, as the distance increases, the high frequencies will be attenuated and not observed on the seismogram. The size of the event also affects the frequencies generated because the fault size is larger. The size of the event depends on the fault size and on the stress causing the earthquake and hence also on the type of rock in which the earthquake occurrs. A larger fault will typically produce more energy in the lower frequencies. The instrument response affects the recorded frequencies by attenuating those frequencies above and below the peak response. Hence, the recorded frequencies will be close to this peak frequency, though they will still vary with the frequency as shown by the Guatamala event (Figure 2e). The surface waves are the longest period waves with periods around 4-10 seconds. They can be seen clearly below the P and S- waves. Figure 2f shows a low frequency (2-6 seconds) motion observed when a weather front crosses the Carters Dam area. This may be related to wind motion coupled to the ground by trees or wave action. The event shown in Figure 2f is probably a large quarry explosion. It shows multiple arrivals in the P-wave which indicate different propagation peaks for the P-waves in the crust.

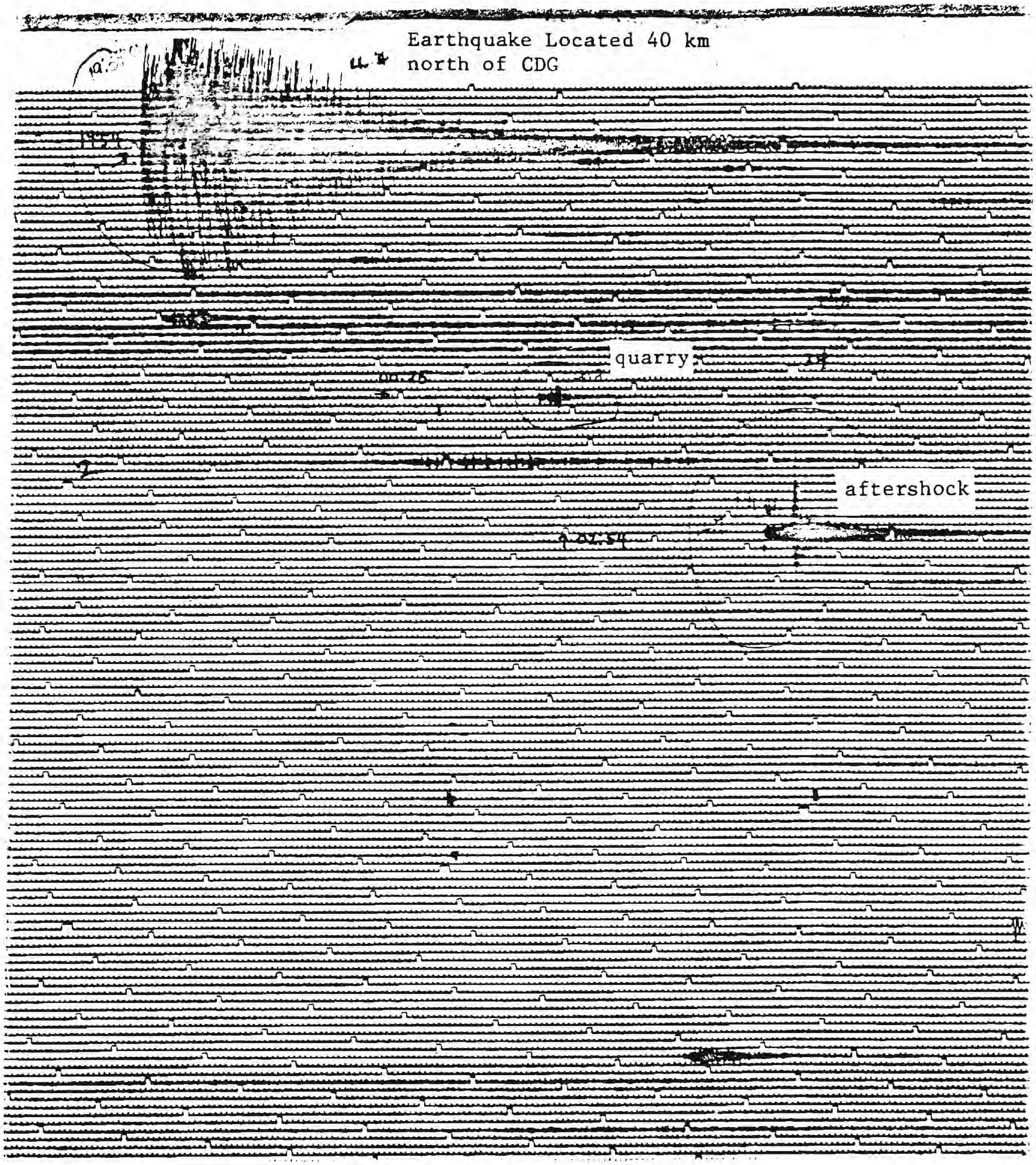
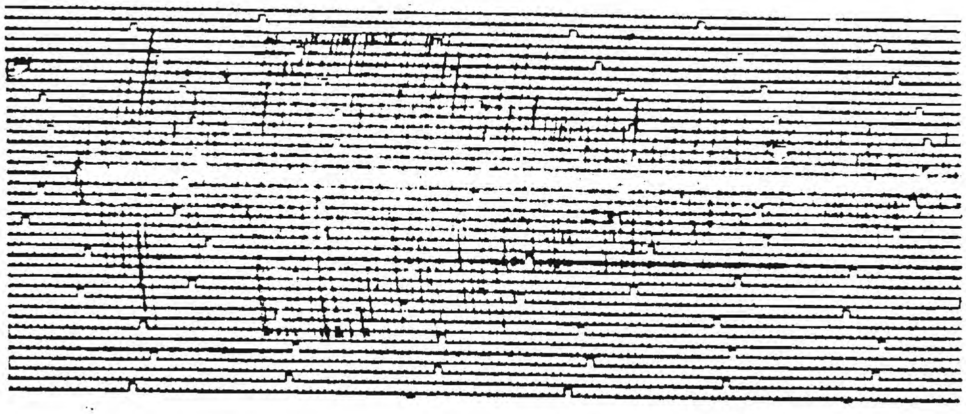


Figure 1. Portion of Seismogram for February 4, 1976.

(a)



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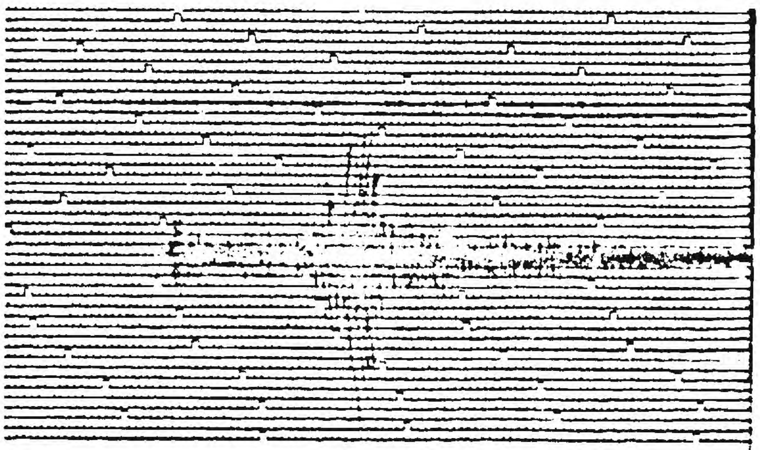

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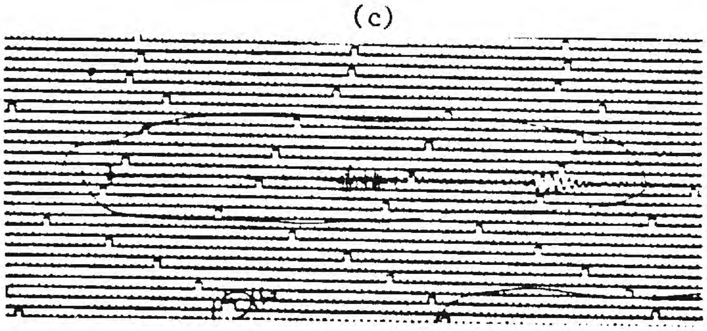
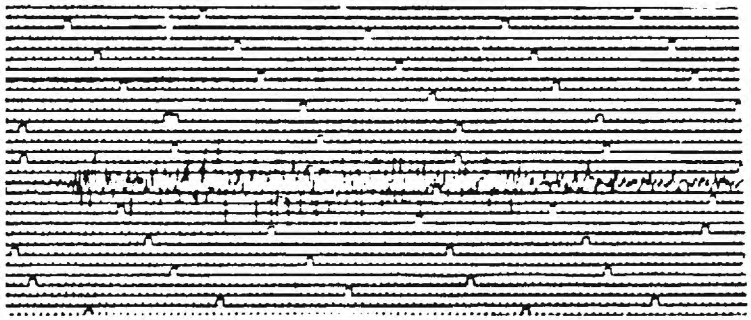
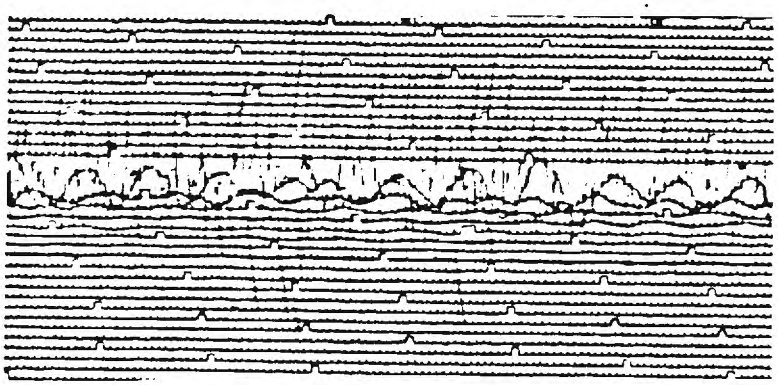


Figure 2 a,b,c. Sample events recorded at CDG.

(d)



(e)



(f)

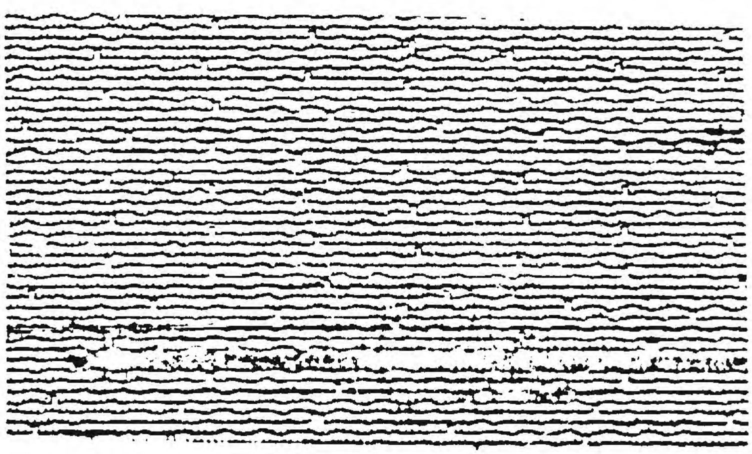


Figure 2 d,e,f. Sample events recorded at CDG.

STATION: Carters Dam, Georgia

ABBREVIATION: CDG

DATE OPEN: January 1, 1975

OPERATED BY: Georgia Tech

GEOGRAPHIC COORDINATES:

LATITUDE: $34^{o}36.65'$

LONGITUDE: $84^{o}40.28'$

ELEVATION: 1150 (ft)
350.5 (m)

ADDRESS: School of Geophysical Sciences
Atlanta, Ga. 30332

ADDRESS TO OBTAIN RECORDS:

School of Geophysical Sciences
Georgia Institute of Technology
Atlanta, Georgia 30332

TELEPHONE NO. (404) 894-2860
TELEX NO.

GEOLOGICAL FOUNDATION:

GEOLOGIC AGE: Metamorphic
Paleozoic Rocks

INSTRUMENTATION:

SEISMOMETER TYPE	COMP.	T_o	GALVO T_g	TYPE OF RECORDING	MAGNIFICATION
Geo-Space 1.0 Hz				Helical Drum- Ink writing	System normally 84 k @ 15 Hz

note: Records are not changed on Saturday, Sunday, or on Holidays.

TIMING SYSTEM:

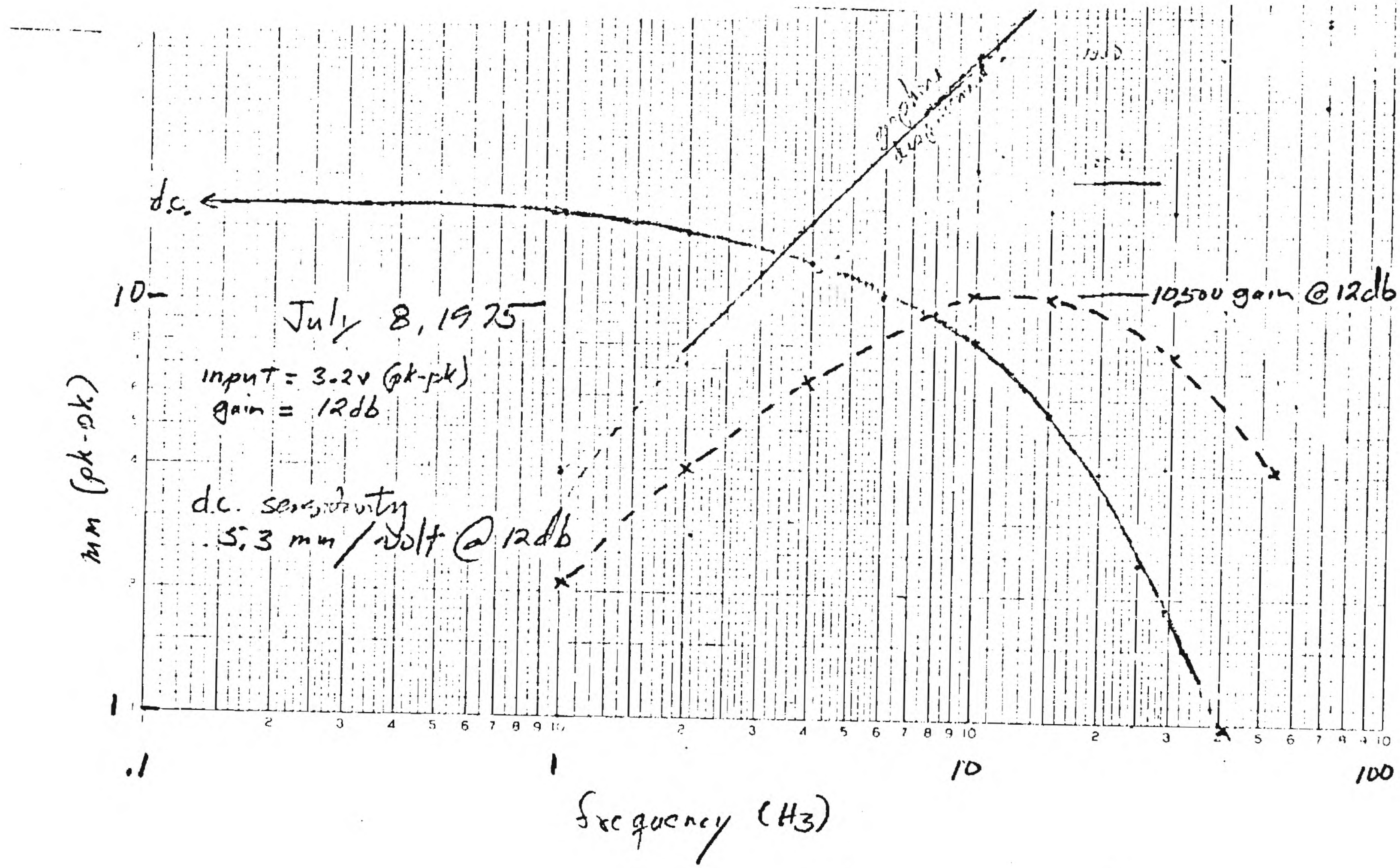
Sprengrether TS-300

SYSTEM RESPONSE CURVES:

see attached

TYPES OF STATION REPORTS DISTRIBUTED BY THE STATION OR THE OPERATING ORGANIZATION:

(CONTINUED ON REVERSE SIDE)


d.c.
10
1
July 8, 1975
input = 3.2v (pk-pk)
gain = 12db
d.c. sensitivity
5.3 mm/volt @ 12db
10500 gain @ 12db
mm (pk-pk)
.1
1
10
100
frequency (Hz)

Subject: Recommendations for seismic monitoring of seismic activity associated with reservoirs

Author: Dr. Leland Timothy Long, School of Geophysical Sciences Georgia Tech, Atlanta, Ga. 30332

Reference: Possible action by Georgia Tech should activity be detected at Carters Dam through microearthquake monitoring activities covered by Contract No. DACW01- 74 - C - 0077.

Reasons for Report: The author has recently had the opportunity to review the data and its analysis for earthquake activity associated with Jocassee Dam in South Carolina. A summary of the program including problems encountered and the more successful techniques utilized might be helpful in formulating plans for action at Carters Dam or other reservoirs associated with seismic activity. Also, on February 4, 1976, 19:59:UT, a magnitude 3.0 earthquake occurred approximately 40 km from the Carters Dam Seismic station. This event was beyond a distance for immediate concern at Carters Dam. However, we did wish to investigate it more closely. The rush of activities that followed made us realize that should an event occur near Carters Dam we would have little time to prepare recommendations of action for the Corps of Engineers to follow. Hence, these recommendations are being prepared in advance.

Recommendations: The following recommendations are based largely on recent experiences at Jocassee Dam in South Carolina and on Georgia Tech's establishment of a net in the Clark Hill Reservoir area. Jocassee Dam is similar to Carters Dam in elevation and height. However, Carters is insulated from basement crystalline rocks by some thickness of sedimentary and metamorphic rocks. In my current opinion, much of the seismic activity observed in the southeast is related to the more rigid features of the crust. The surface rocks play a secondary role in any seismic activity that might occur. In the case of Jocassee, the crystaline rocks are near the surface and most of the earthquakes are at depths less than 2.0 km. I believe significant activity at Carters Dam would in contrast be at depths 1 to 3 km or if shallower, in the harder rocks to the east of the Dam. If earthquakes are to be triggered by changes in pore pressure, then additional time might be required for the changes in water pressures to penetrate the surface sedimentary and metamorphic rocks. At Jocassee, in comparison, the activity initiated about 1-3 yr after filling. If there is stress in the rock which might be released by a change in pore pressure at Carter's then activity might be delayed two or more years.

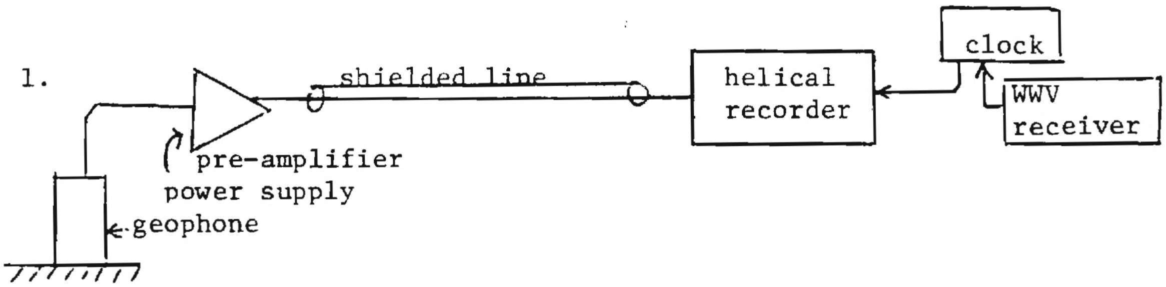
A. The first recommendation is that all reservoirs establish a monitoring system for simple detection of local events. Ideally, the system should be operated continuously starting at least 1 year before filling of the reservoir and continuing as long as the reservoir exists. While most activity occurs during or just after loading, continued operation would provide valuable regional seismic data. Monitoring at Jocassee was not initiated until an earthquake was felt locally and identified by local seismologist. Potentially valuable information on foreshock activity may have been lost. The type of instrument recommended would be a short-period vertical seismometer recorded on a helical drum recorder with timing precision of 0.1 sec or better. This is the type of instrument currently in operation at Carters Dam. However, the recording site does not have to be at the Dam Site since telemetry systems can provide similar quality data recorded at distance. Georgia Tech currently has two operational systems which use telephone telemetry to record in Atlanta data from the Clark Hill Reservoir area. Recording at Georgia Tech makes it easier to maintain continuous records. A similar system could be installed at Carters Dam for recording at Georgia Tech to reduce personal involvement at Carters Dam and obtain seven days of data each week but there would be a monthly phone line charge.

B. The second reccomendation is that if activity is identified, seismic monitoring should be achieved with an array consisting of 3 to 5 portable microearthquake recorders. This would be short term and the primary objective would be to locate the activity and provide a more accurate measure of the level of activity. Should activity be detected at Carters Dam, Georgia Tech would investigate with portable recorders. The short-term investigations would probably be partially supported by other grants in effect at Georgia Tech. The results of these studies could be used to help decide whether long-term multi-station monitoring should be initiated to obtain the quality and amount of data necessary for prediction.

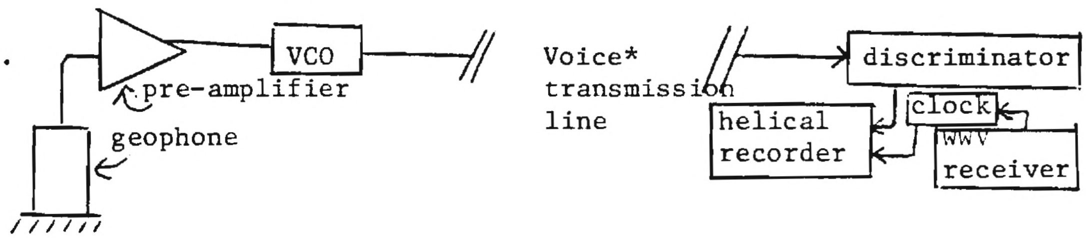
C. The third recommendation is that if long-term (i.e greater than 6 mo.) recording is advised, this should be achieved with a centrally recorded net. The initial expense may seem objectionable, particularly when considering the hope that the monitoring will be short term. The advantages in the quality and consistancy of the data far outweigh any savings realized in using portable units. In particular, the use of a single time reference eliminates errors introduced by attempts to syncronize at least six clocks to within ± 0.02 seconds. Also, there is no delay in obtaining data from the field and there is a closer control on the quality of the data. With a monitoring program using about 6 centrally recorded stations, one objective would be the measurement of possible earthquake predictors. For example, to use the ratio V_p/V_s effectively as a predictor the data must be precise and a base line must be known. For timely prediction the data should be available for analysis within two days if not immediately. In contrast, the portable systems used at Jocassee require two field technicians vitually full time and there is an inherent two to four day delay in examining the data. Also, while the multiple-organization analysis arrangements may be unusual at Jocassee, the use of copies of smoked paper records imposed on one organization is unacceptable if quality results are required. The results of Long-term monitoring would include activity levels, b values, hypocenters, focal plane solutions and possibly V_p/V_s ratios. This data, combined with a study of the local geology could be used to evaluate the significance of the seismic activity and indicate whether continued detailed monitoring is advisable. In particular this data could be used to estimate the maximum earthquake to be expected and thus allow evaluation of the response of the structure to such an earthquake.

Instrument Systems Compatable with Reccomendations

A. 1.



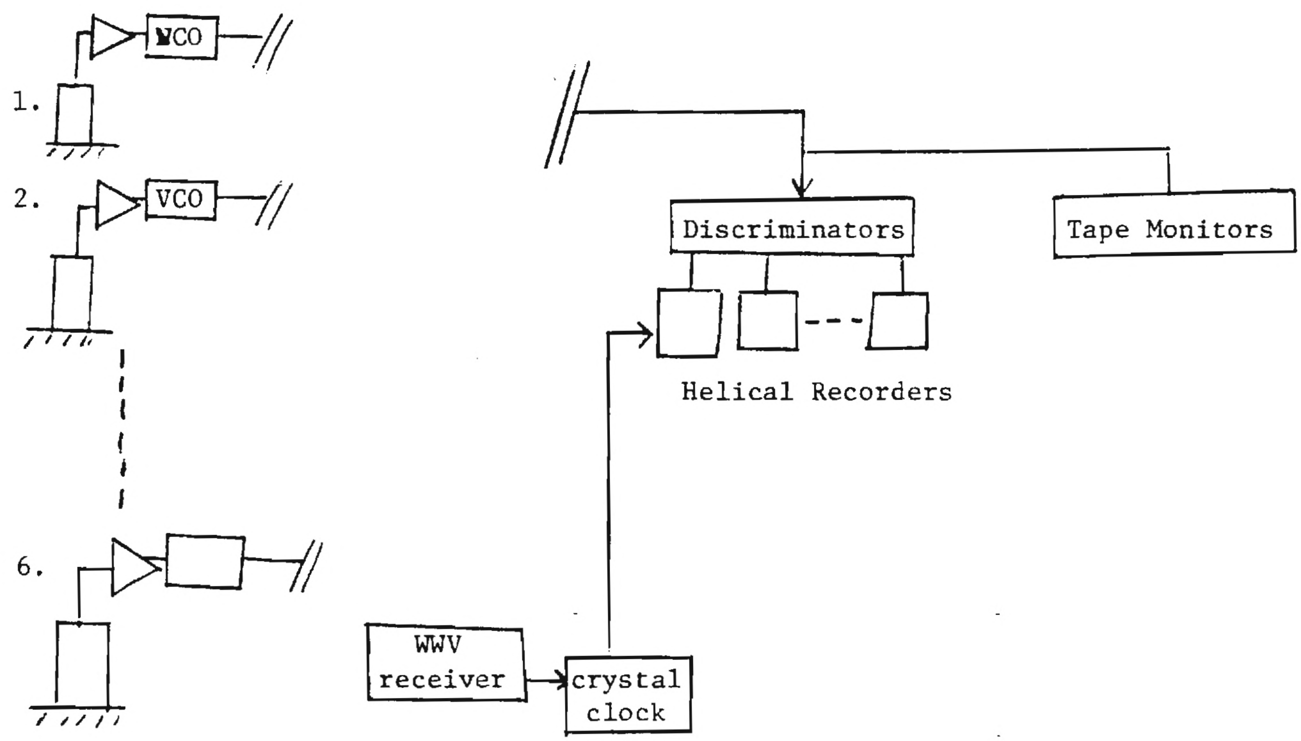
2.



*note: if one channel is used the dynamic range is significantly greater than if 6 are multiplexed on oreline

B. Any commercial helical smoked paper recorder or portable tape recorder

C.



A LOCAL MAGNITUDE SCALE FOR CARTERS DAM

Introduction

The Carters Dam Seismic Station or CDG as designated by the USGS was established by Georgia Tech at the request of the U.S. Army Corps of Engineers in order to monitor the vicinity of the reservoir for possible earthquakes. No significant events were detected in the vicinity of the reservoir during filling. However, numerous regional events and explosions were recorded by the Carters Dam seismograph. The object of this report is to utilize some of these events to develop a local magnitude scale for the Carters Dam Station.

The frequency response of CDG is designed for the 5 to 20 Hz range to allow better detection capability for local events. Also, local irregularities in crustal structure may effect the character of the local events at CDG. Hence, the existing published magnitude scales may not be appropriate for local events recorded at CDG. The development of a local magnitude scale for CDG will allow estimation of the magnitude of local events as well as determination of the magnitudes of regional events.

Method

The local magnitude equation for Carters Dam was expressed as:

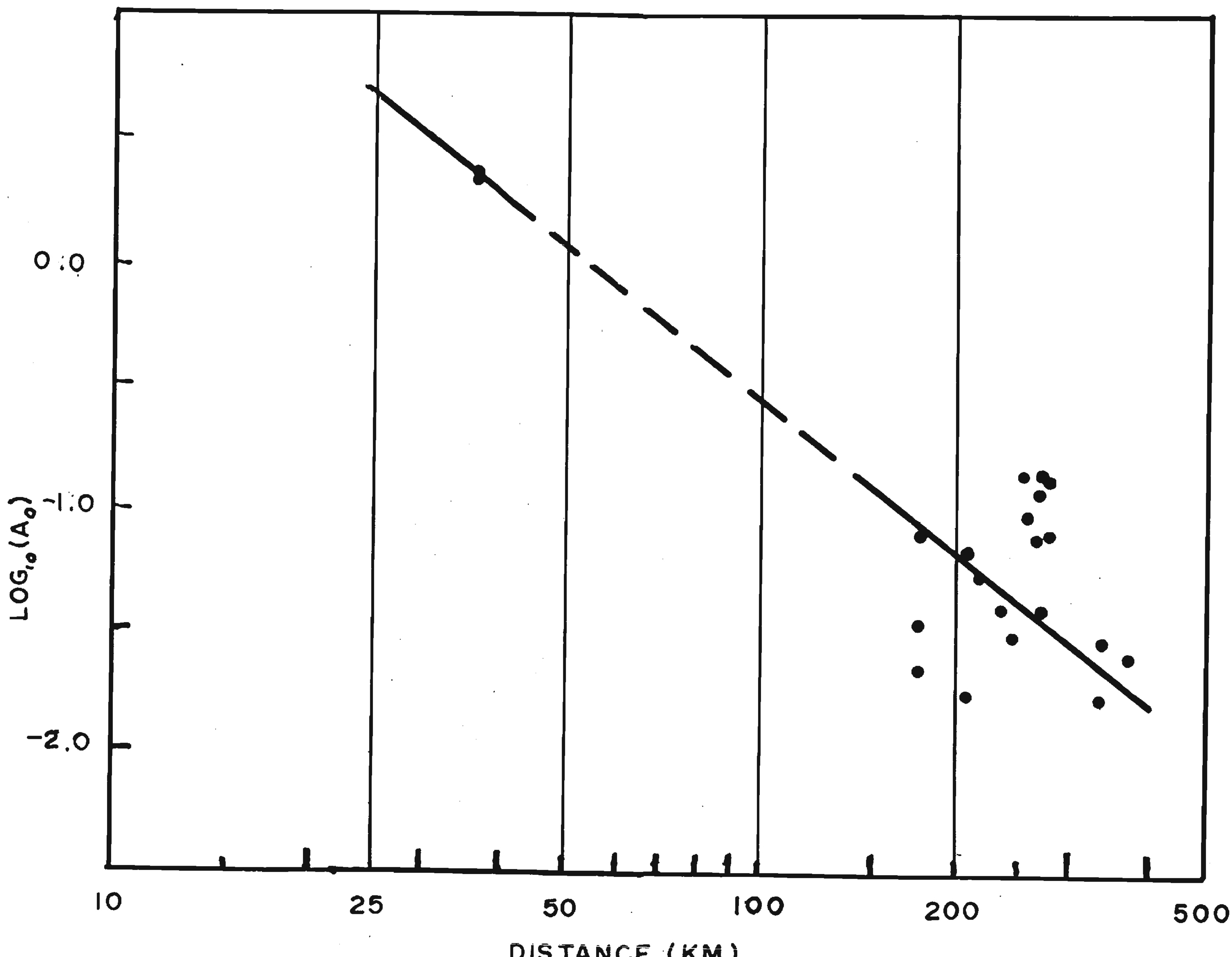
$$M_{LCD} = \text{Log } (A/T) - \text{Log}(A_o)$$

where A is the observed trace amplitude (mm) at 84 k gain of the L_g phase at Carters Dam , T is the period (normally about 0.1 sec) and A_o is expected amplitude of a zero magnitude event. In order to calculate A_o for CDG, events recorded at both CDG and ATL were used. The local magnitude was computed at ATL for the event and then used in the above equation to solve for $\mathrm{Log}(A_o)$.

Twenty-two events were found to be large enough to use in the computations (see Table I). The resulting values of $\mathrm{Log}(A_o)$ are shown in figure 1. The existing data imply an uncertainty of $\pm$ 0.5 magnitude units. Given a 1.0 mm trace amplitude (at 10 Hertz) for an event at 10 km implys a detection threshold of magnitude -0.5 at 10 km .

TABLE I

DATE (mo day yr)	ATL Max. Amp. (mm)	ATL Dist. (km)	ATL Azimuth (deg.)	ATL M_L	CDG Max. Amp. (mm)	CDG Dist. (km)	CDG $\text{Log}_{10}(A_.)$
8 14 75	2.0	452	295	2.94	2.5	337	-1.54
8 29 75	3.6	279	220	2.50	4.2	279	- .88
10 21 75	5.3	246	220	2.87	2.8	238	-1.42
10 22 75	2.1	312	65	2.82	3.9	221	-1.23
10 22 75	3.2	227	220	2.45	1.1	271	-1.41
11 3 75	2.6	267	220	2.36	1.8	279	-1.10
11 19 75	3.8	268	220	2.52	2.5	267	-1.12
11 25 75	22.0	210	70	3.49	10.7	172	-1.46
12 8 75	1.1	215	70	2.18	1.2	170	-1.10
12 8 75	2.1	361	65	2.82	2.0	246	-1.52
12 9 75	3.0	271	220	2.42	2.5	258	-1.02
12 11 75	1.9	304	0	2.95	2.0	172	-1.65
12 12 75	2.2	271	220	2.29	2.7	271	- .86
12 12 75	1.9	205	220	2.42	3.0	211	- .94
12 16 75	4.1	443	295	3.26	3.0	337	-1.78
12 17 75	1.8	221	220	2.40	1.7	205	-1.17
12 19 75	5.3	435	295	3.37	5.7	370	-1.61
12 29 75	2.2	279	220	2.29	2.7	254	- .86
12 29 75	2.3	304	295	3.21	2.8	205	-1.76
2 4 76	1.1	166	352	1.97	20.49	37	.350
2 5 76	0.75	166	352	1.81	13.6	37	.32
1 19 76	1.6	166	352	2.14	28.0	37	.31


0.0
-1.0
-2.0
$LOG_{10}(A_0)$
10
25
50
100
200
500
DISTANCE (KM)